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DIVISION OF EXACT SCIENCES

DEPARTMENTS OF MATHEMATICS
PHYSICS AND CHEMISTRY

1910

WORCESTER, MASSACHUSETTS

CALENDAR 1910-1911

1910			
April	4	Monday	Spring Recess
April	9	Saturday	
April	19	Tuesday	Patriot's Day
May	30	Monday	Memorial Day
June	16	Thursday	Twenty-first academic year closes
		Summer Vacation of 14 Weeks	
Sept.	22	Thursday	Twenty-second academic year begins
Nov.	24	Thursday	Thanksgiving Day
Dec.	26	Monday	Christmas Recess
1911			
Jan.	7	Saturday	
Feb.	1	Wednesday	Founder's Day*
Feb.	22	Wednesday	Washington's Birthday
April	3	Monday	Spring Recess
April	8	Saturday	
April	19	Wednesday	Patriots' Day
May	30	Tuesday	Memorial Day
June	15	Thursday	Twenty-second academic year closes

*Not a holiday

Clark University

Worcester, Massachusetts

Division of Exact Sciences

DEPARTMENTS OF MATHEMATICS, PHYSICS AND CHEMISTRY

G. STANLEY HALL, PH.D., LL. D.
President of the University

HENRY TABER
Chairman of the Division

J. C. HUBBARD
Secretary of the Division

DEPARTMENT OF MATHEMATICS

WILLIAM EDWARD STORY, PH. D.
Professor of Mathematics

A. B., Harvard University, 1871; Parker Fellow, 1874-75; Student, Universities of Berlin and Leipzig, 1871-75; Ph. D., Leipzig, 1875; Tutor of Mathematics, Harvard University, 1875-76; Associate, Assistant Professor and Associate Professor of Mathematics, Johns Hopkins University, 1876-89; Professor of Mathematics, Clark University, 1889-; Professor of Mathematics, Clark College, 1902-07; Member of the National Academy of Sciences; Member of the London Mathematical Society and of the American Mathematical Society; Resident Fellow of the American Academy of Arts and Sciences; Fellow of the American Association for the Advancement of Science.

HENRY TABER, PH. D.
Professor of Mathematics

Ph. B., Yale University, 1882; Ph. D., Johns Hopkins University, 1888; Assistant in Mathematics, Johns Hopkins University, 1888-89; Docent in Mathematics, Clark University, 1889-92; Assistant Professor, 1892-1903; Professor, 1903-; Member of the London Mathematical Society; Member of the Deutsche Mathematische Vereinigung; Member of the American Mathematical Society; Resident Fellow of the American Academy of Arts and Sciences.

JOSEPH DE PEROTT
Lecturer in Mathematics

Student, Universities of Paris and Berlin, 1877-80; Docent in Mathematics, Clark University, 1890-1904; Lecturer, 1904-.

FRANK B WILLIAMS, PH. D.
Collegiate Professor of Mathematics

C. E., Missouri State University, 1890; Teaching Fellow in Mathematics, 1892-93; M. S., 1893; Scholar in Mathematics, Clark University, 1897-98; Fellow, 1898-1900; Ph. D., 1900; Assistant Professor of Mathematics, Union College, 1900-07; Assistant Professor of Mathematics, Clark College, 1907-8; Professor of Mathematics, Clark College, 1908- .

DEPARTMENT OF PHYSICS

ARTHUR GORDON WEBSTER, PH. D., D. Sc., LL. D.
Professor of Physics and Director of the Physical Laboratories

A. B., Harvard University, 1885; Instructor in Mathematics, Harvard University, 1885-86; Parker Fellow, 1886-89; Student, Universities of Berlin, Paris, Stockholm, 1886-90; Ph. D., Berlin, 1890; Docent in Physics, Clark University, 1890-92; Assistant Professor, 1892-1900; Professor, 1900- ; Professor of Physics, Clark College, 1902-07; D. Sc., Tufts College, 1905; LL. D., Hobart College, 1908; Member of National Academy of Sciences; Member American Philosophical Society; President, 1903-05; American Physical Society; Resident Fellow of the American Academy of Arts and Sciences; Fellow, American Association for the Advancement of Science; Member American Mathematical Society, Deutsche Mathematiker-Vereinigung, Circolo Matematco di Palermo.

JOHN CHARLES HUBBARD, PH. D.
Instructor in Physics and Collegiate Assistant Professor of Physics

B. S., University of Colorado, 1901; Scholar in Physics, Clark University, and Assistant to Professor Webster, 1901-02; Fellow, 1902-04; Ph. D., Clark University, 1904; Honorary Fellow, *ibid.*, 1906-09; Instructor, 1909- ; Instructor in Physics, Simmons College, 1904-05; Assistant Professor of Physics, and Secretary of the Faculty of Applied Science, New York University, 1905-06; Assistant Professor of Physics, Clark College, 1906- .

THOMAS LANSING PORTER, A. M.
Research Assistant to Professor Webster

B. S., Northwestern University, 1907; Laboratory Assistant in Physics, *ibid.*, 1906-07; Research Assistant to Professor Webster, Clark University; 1907-08; A. M., Clark University, 1908; Honorary Fellow, *ibid.*, 1908-9; Instructor in Physics, Clark College 1908-09.

DEPARTMENT OF CHEMISTRY

MARTIN A. ROSANOFF, Sc. D.
Assistant Professor of Chemistry and Director of the Chemical Laboratories

Ph. B., New York University, 1895; Sc. D., 1908; Student, University of Berlin, 1895-96; Research Laboratory of Organic Chemistry, University of Paris, 1896-98; Research Assistant to Dr. J. M. Crafts, Boston, Mass., 1898-

99; Research Fellow, New York University, 1899-1900; Editor for Exact Science in the New International Encyclopædia, 1900-03; Research Assistant to Mr. Thomas A. Edison, Orange, N. J., 1903-04; Instructor in Theoretical Chemistry, New York University, 1904-05; Assistant Professor of Chemistry, 1905-07; Head of the Chemical Department with the title of Assistant Professor of Chemistry, Clark University, and Assistant Professor of Organic Chemistry, Clark College, 1907; Fellow of the American Association for the Advancement of Science.

BENJAMIN S. MERIGOLD, PH. D.
Instructor in Chemistry and Collegiate Professor of Chemistry

A. B., Harvard University, 1896; A. M., 1897; Ph. D., 1901; Assistant in Chemistry, Harvard University, 1896-1900; Instructor in Chemistry, Worcester Polytechnic Institute, 1900-03; Assistant Professor of Chemistry, Clark College, 1903-08; Professor, 1908- ; Instructor in Chemistry, Clark University, 1905- .

ROBERT HARVEY CLARK, PH. D.
Docent in Chemistry

A. B., University of Toronto, 1905; A. M., 1906; Ph. D., University of Leipzig, 1908; Assistant in Chemistry, University of Toronto, 1905-06; 1851 Exhibition Science Research Scholar, University of Leipzig, 1906-09; Acting Assistant Professor of Chemistry, Clark College, 1909- .

NON-RESIDENT UNIVERSITY LECTURER

ARTHUR A. NOYES, PH. D., SC. D., LL. D.
Non-Resident University Lecturer in Chemical Research

Professor of Theoretical Chemistry; Director of the Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

GENERAL STATEMENT

CLARK UNIVERSITY was established in the City of Worcester in 1889. The object of the University is to promote scientific research and to provide by suitable instruction and guidance a foundation of knowledge and experience for those desiring to become specialists and teachers in higher institutions of learning. The number of departments has been purposely limited. It has been from the beginning the settled policy of the institution to first strengthen departments already established until they are as thorough, as advanced, as special, and as efficient as possible, before proceeding to the establishment of new ones.

Several thousand memoirs and many books have been published by members of the University since its establishment and the former students, numbering nearly a thousand, are scattered over the country in University and College work, many of them occupying positions of high rank.

The University now consists of nine departments, as follows:

I. MATHEMATICS.
II. PHYSICS.
III. CHEMISTRY.
IV. BIOLOGY.
V. ANTHROPOLOGY.
VI. PSYCHOLOGY.

VII. Pedagogy.
VIII. Economics and Sociology.
IX. History.

For the purpose of better correlating instruction and of securing closer personal supervision of the work of students, the departments of Mathematics, Physics, and Chemistry have this year been organized into a Division of Exact Sciences.

The Advantages Offered by the University

The most prominent feature of Clark University is *the close relationship of the instructors and investigators in the several departments with their students.* The staff is large in comparison with the number of men taking instruction and doing research, and most of the University staff have no connection with Collegiate teaching, the burden of professors in most American universities. The whole time of the professor is thus available for a comparatively small number of students, and it becomes possible for him to know intimately the needs and capacity of each; the individual guidance by and contact with men of recognized attainments thus secured enhancing efficiency and stimulating zeal to a degree which would be impossible in a large institution. Too much cannot be said of a system which places the beginner in such close relationship with an investigator that he can see science in the making from the beginning of his University career.

Seminaries or colloquia are held regularly in each of the departments, at which each student is expected from time to time to take part, presenting results of his own work or reports of classical or recent experimental or theoretical work. This exercise is invalu-

able in training the student to present ideas and to think clearly before a critical audience.

In connection with the newly organized Division of Exact Sciences is being carried on a study of methods and aims and the needs of students. It is believed that the results will secure for students the most effective and efficient programmes according to their various purposes.

Arrangements are well under way for securing a number of eminent men of science as non-resident lecturers. These men will visit the University from time to time and present the newest results and developments in their own special fields.

Worthy of mention is the relationship of the work of the University to that of Clark College, an institution having a separate endowment, classrooms, laboratories and library, and its own president and faculty. The University and College are thus enabled to concentrate upon the problems peculiar to the sphere of each, and yet to receive mutual benefit. Men coming to the University who feel a need of further preparation for their work have an opportunity of receiving instruction in collegiate courses.

The scientific laboratories of Clark University are supported by ample annual appropriations, which enable each department to carry on efficiently any desired research. The University conducts a well appointed shop in which many of the instruments required are constructed, and where repairs and alterations may be quickly made. The laboratories are large and pleasant and afford space and facilities for many lines of research.

The library is growing rapidly and contains valuable

sets of periodicals and is notably complete in the lines of work represented by the existing departments. The reading room receives over 500 journals. The administration of the library is unique in its helpfulness and liberality. The need of a book has only to be mentioned, and the book is secured. There is no limit to the number of books which may be withdrawn, and there is no limit to the time which each book may be kept, consistent with the needs of others. Every member of the University has direct access to each book and journal. Card indices of titles are being prepared under the supervision of members of the Division. These are already very complete in many lines of research and are proving a valuable supplement to the usual monthly and annual lists issued by the journals.

The location of the University in a cosmopolitan city of 140,000 people, and within an hour's ride from Boston, secures for its members easy access to music and art and to the notable museums and libraries in this region. The Worcester Art Museum is one of the best endowed in this country. In this city are the Library of the American Antiquarian Society, organized in 1812, and containing over 120,000 volumes, and the Worcester Public Library, receiving 600 newspapers and magazines and containing 165,000 volumes, both free to members of the University. A system of exchange enables students to secure books from the American Academy of Arts and Sciences in Boston, and from Harvard University.

Admission

Only graduate students are admitted, or those of equivalent attainments. At present, no entrance exam-

inations are required, but, by testimonials, diplomas, or personal interviews the authorities must be satisfied that the applicant has scholarship enough to work to advantage.

Candidates for Degrees

The University confers two degrees, the degree of Doctor of Philosophy, and the degree of Master of Arts.

The degree of *Doctor of Philosophy* requires at least one year, but in most cases two or three years, of residence in graduate work, and is given when the candidate shall have satisfied the authorities by suitable examination and by the preparation of a dissertation embodying the results of original investigation that the candidate possesses fitness for the degree.

The degree of *Master of Arts* is conferred upon a candidate who has spent one year in graduate study and who has satisfied the authorities by suitable examination and the preparation of a thesis that the candidate possesses fitness for the degree. The selection of studies may be such as to be preliminary for teaching, preparation for professional study, technical work, or a tentative beginning for the doctorate, or for purely cultural purposes, and candidates are encouraged to choose such studies as may accomplish their ends as effectively and definitely as possible. Candidates may choose any courses offered by the University provided they are prepared to pursue such courses with profit. The courses in the departments constituting this division and in the department of Pedagogy afford special training for those who wish to become teachers of science.

Special Students

In addition to candidates for degrees the University may receive students who wish to pursue some approved line of research and whose attainments are such as to satisfy the requirements of the University, but who do not care to matriculate or become candidates for the degree. Such students may be allowed entire freedom in their choice of studies and may enjoy all the privileges of the University.

Fellowships and Scholarships

Fellowships and scholarships at Clark University are intended to aid young men and women of promise who desire to pursue post-graduate studies in order to fit themselves for intellectual careers. There are no duties attached to these positions aside from making the best use of the facilities of the University for study and research. It is desirable, but not required, that candidates for fellowships should intend to proceed to the degree of Doctor of Philosophy or to equivalent attainments. In general, those intending to devote themselves to some special branch of learning are preferred to those directly fitting themselves for one of the three learned professions, although the latter are not excluded.

No application blanks are provided, but it is desired that the candidate should state fully and in writing his previous course of study and submit testimonials or diplomas, especially such as indicate a decided preference for some particular department. These should be accompanied also, if practicable, by some specimen of the candidate's work. Applications will be considered in June and in October and should be in the hands of the President on or before the first day of either month.

In special cases vacancies may be filled by appointments at any time during the year. The names of unsuccessful candidates will not be made public.

Fees

Students not holding fellowships or scholarships are expected to pay a fee of $100 per annum. Exception is made in the case of graduates of Clark College, and of other Worcester Institutions of Collegiate grade, from whom no fee is required.

Board and Rooms

A dining hall is conducted by Clark College, all the privileges of which are open to the students of the University. Excellent board is given for four dollars weekly. Board at other rates may be secured outside. All possible aid is given in securing board and rooms for students. Rooms vary from one dollar weekly up, according to location and conveniences.

Information

Intending students and others interested in Mathematics, Physics or Chemistry are invited to address inquiries relating to admission, fellowships or scholarships, or general information, to the Secretary of the Division, J. C. Hubbard, Clark University, Worcester, Mass.

DEPARTMENT OF MATHEMATICS

The chief aim of the department is to make independent investigators of such students as have mathematical taste and ability; these naturally look forward to careers as teachers of the higher mathematics in colleges and universities, and we believe that the course of training best adapted to the development of investigators is also that which is most suitable for all who would be efficient college professors, even if they are not ambitious to engage in research. The first essential of success in either of these lines is the habit of mathmetical thought, and the direct object of our instruction is the acquisition of this habit by each of our students. With this end in view, we expect every student to make himself familiar with the general methods and most salient results of a large number of different branches of mathematics, conversant with the detailed results and the literature of a few branches, and thorough master of at least one special topic to the extent of making a real contribution to our knowledge of that subject.

In accordance with these principles, the instruction is given by means of introductory, advanced, and special courses of lectures, seminaries, and personal guidance in reading and investigation.

The introductory courses (mostly given in alternate years) treat the following subjects:

ANALYTIC GEOMETRY OF HIGHER PLANE CURVES, HIGHER SURFACES, AND TWISTED CURVES; 5 hours a week, through the year.

Differential Equations, and Calculus of Variations; 5 hours a week, through the year.

Theory of Functions of Real and Imaginary Variables, Elliptic Functions, and Definite Integrals; 5 hours a week, through the year.

Theory of Numbers; 2 hours a week, one half-year.

Modern Synthetic Geometry; 2 hours a week, one half-year.

Algebraic Substitutions and their Application to the Theory of Equations; 2 hours a week, one half-year.

Algebraic Invariants; 2 hours a week, one half-year.

Finite Differences; 2 hours a week, one half-year.

It is expected that every student will take each course in the earliest year of his residence in which it is given, unless he has already completed an equivalent course elsewhere. The chief object of these courses is to make the student familiar with the various methods of mathematical research and the concepts of mathematical thought at the present day. Thus, for example, curves and surfaces are treated by modern methods from the beginning, with adequate consideration of the discoveries of the great geometers of recent times. The usual college courses in the theory of algebraic equations, analytic geometry, and the differential and integral calculus furnish all the necessary preparation for these introductory courses, although it is very desirable that the student be acquainted with the properties of determinants and their application to the solution of linear equations, and with the methods of solving differential equations of the simpler types. Deficiencies in these subjects may be made up by attendance on the corresponding courses in the Collegiate Department of the University.

Special advanced courses, open to all who are pre-

pared for them, are given annually in subjects varying with the interests of the instructors and the needs of the students. These advanced courses are not repeated at regular intervals, but properly prepared students will receive the personal assistance of one or other of the instructors in reading any subject not announced for the year in which they desire to take it.

The number and scope of the advanced courses given each year have been, thus far, regulated by the number of students qualified to profit by them and by the individual interests of the instructors; these courses will be increased, both in number and variety, whenever a real demand for such an increase shall make itself apparent. While the present purely scientific character of the University precludes instruction in strictly technical branches, we hope that the time is not far distant when the demand shall make it advisable, and increased facilities shall make it possible, to announce courses in Descriptive Geometry, Graphical Statics, Mathematical Astronomy, Vital Probabilities, and all the more important applications of mathematics to other sciences and to technical subjects. The applications of mathematics to physics already receive adequate consideration, and the further extension of such applications awaits only a demand for it on the part of students.

The subjects in which advanced courses may be expected to be given every few years include the following:

History of Mathematics:

Arithmetic: Numerical computations; Theory of numbers; Finite differences and the Calculus of operations; Probabilities and the Theory of errors.

Algebra: Substitution-groups and the Galois theory of equations; Invariants; Quadratic forms; Simultaneous equations (including Restricted systems); Multiple algebra.

HIGHER ANALYSIS: Differential equations, ordinary and partial; Continuous groups; Definite integrals and Fourier's series.

THEORY OF FUNCTIONS: Functions of real and complex variables; Point-aggregates; Elliptic functions; Abelian integrals.

GEOMETRY: Modern synthetic geometry; Analytic geometry of higher plane curves, higher surfaces, and twisted curves; Rational and uniform transformations of curves and surfaces; Infinitesimal geometry; Analysis situs; Quaternions.

SYMBOLIC LOGIC.

Other courses will be given whenever there is a demand for them, as in the past. The instructors are always glad to assist students in any line of mathematics that falls within the range of their own studies. The small number of students makes it possible to give personal attention to individuals, and the intimate and confidential relation thus established between pupil and teacher is an advantage that cannot be overestimated and ought not to be left out of account by the prospective student in determining where his studies shall be pursued.

For the academic year 1910-11, the following courses of lectures are announced:

BY PROFESSOR STORY

Introductory course:

ANALYTIC GEOMETRY OF HIGHER PLANE CURVES, HIGHER SURFACES, AND TWISTED CURVES; 5 hours a week, through the year.

Advanced courses:

HISTORY OF MATHEMATICS; 2 hours a week, first half-year.

THEORY OF ERRORS; 2 hours a week, second half-year.

FINITE DIFFERENCES AND CALCULUS OF OPERATIONS; 2 hours a week, through the year.

SEMINARY for advanced students, through the year.

BY PROFESSOR TABER

Introductory course:

THEORY OF FUNCTIONS OF COMPLEX VARIABLES, ELLIPTIC FUNCTIONS, AND DEFINITE INTEGRALS; 5 hours a week, through the year.

Advanced courses:

THEORY OF BILINEAR FORMS; 2 hours a week, first half-year.

THEORY OF INTEGRAL EQUATIONS; 2 hours a week, second half-year.

SEMINARY, through the year.

BY PROFESSOR WEBSTER

[See announcement of the Department of Physics.]

BY M. DE PEROTT

Introductory course:

THEORY OF NUMBERS; 2 hours a week, first half-year.

Advanced course:

ABELIAN INTEGRALS AND RIEMANN SURFACES; 2 hours a week, second half-year.

BY DR. WILLIAMS

ADVANCED ALGEBRA; 2 hours a week, through the year.

While desirous of supplying all possible facilities to those who wish to pursue studies in special branches, and to those who, already occupying permanent positions, have but a limited leave of absence, we have made it our chief object to provide a thorough training for those who, having just completed a college course, have not yet entered upon their life-work. This provision consists of such courses of lectures, seminaries, and individual assistance as should enable a faithful student endowed with the proper natural ability to satisfy the requirements for the degree of Doctor of Philosophy at the end of his third year with us. The requirements for this degree have been determined by our conception of the ideal teacher, as already stated.

To acquire the necessary breadth of knowledge of mathematics as a whole, the candidate is expected to attend, during his first two years, specified introductory courses of lectures on the general principles, methods, and results of all the more important branches of pure mathematics, to supplement these lectures by private reading and to take an active part in the seminary. In the seminary, a special topic, more or less directly connected with the subject of some lecture, is assigned, from time to time, to each student, who is required to read it up and make an oral report upon it before the class. Each candidate for the degree is expected to attend a number of advanced courses. He spends the greater part of his third year in the original investigation, under the constant personal guidance of one of the instructors, of a topic of his own selection. In preparing for this investigation he is required to make a practically complete bibliography of the subject and to read all the more important available articles that have been written on it. The results of the investigation, embodied in a dissertation suitable for printing, must be submitted to the instructor under whose direction the work was done, and must receive his approval before the candidate will be admitted to the final examination for the degree. This approval will not be given unless the dissertation is satisfactory in form and completeness and the results are sufficiently novel and important to constitute a real contribution to science. The dissertation is, in fact, the main criterion by which the candidate is judged, and no amount of other work will compensate for its defects.

Each of the instructors is engaged in research and has always a number of investigations planned for himself,

which have often been carried to a well advanced stage, but are not completed for want of time. Such incomplete investigations are given to properly prepared candidates for the Doctor's degree, and they receive from the instructor all the assistance necessary for the completion of the work, thus becoming, to a certain extent, collaborateurs with the instructor.

The preparation of a bibliography of any topic is greatly facilitated by a classified index of mathematical literature on the card-catalogue plan, which has been prepared under the supervision of Professor Story and now includes nearly one hundred thousand titles of periodical articles, separate memoirs, and books in all fields of pure mathematics. This index is much more complete than the Royal Society's catalogue, even in the restricted field of that catalogue (periodicals published between 1800 and 1900), and will be extended as rapidly as possible.

The ability of our graduates to carry on research and the excellence of the work actually done is assured by the regulation that each dissertation accepted by us as worthy of the degree shall be printed with the explicit approval of a member of our Faculty. It is evident that, whereas any one that has the necessary preparation and taste for mathematics may profit by the advantages here afforded, only those who have a certain amount of mathematical genius can secure the degree.

In making appointments to fellowships and scholarships we have endeavored to maintain the same high standard. We are on the lookout for mathematical geniuses; but it is difficult to determine from the evidence of others whether candidates come up to our standard or not; so that we have adopted the general policy of

giving the best appointments to those only that have been with us for at least one year, and about whom we are in position to judge for ourselves. Of course, this policy could not be carried out during the earlier years of the University, and its effect is apparent in the fact that, whereas seventy-five per cent. of the students that entered the mathematical department during the first three years remained with us but one year, only thirty-three per cent. of those that have been admitted during the years 1892-1909 left at the end of their first year. We do not mean to imply that those who left before completing our course were inferior in ability to those who remained three years, but we desire particularly to encourage men who can and will go forward to the degree.

Nearly all of those who have studied mathematics with us have adopted teaching as a profession, sixty-eight per cent. are now members of college faculties, and thirteen per cent. are engaged in higher school work. Those who have received the doctor's degree have generally secured at once desirable positions in which to begin their life-work, and most of them have already acquired for themselves, by distinguished ability, very decided influence in the institutions with which they are connected.

The degree of Master of Arts will be conferred upon students who complete with credit an approved course of one year and present a satisfactory thesis.

Every facility for the study of special branches will be given to properly prepared students who are not candidates for a degree, as also to those who, having already attained to the doctor's degree (here or elsewhere), wish to continue mathematical study or investigation.

Material Facilities

The library is provided with the more important text-books, treatises, and memoirs on the various branches of mathematics, as well as the principal journals and transactions of learned societies that are devoted to any considerable extent to mathematics. Among the periodicals are the following:

Acta mathematica. Stockholm, Berlin and Paris, 1882 to date. Complete.

American association for the advancement of Science. Proceedings, 1848 to date. Complete.

American journal of mathematics. Baltimore, 1878 to date. Complete.

American Mathematical Society.

Bulletin. 1894 to date. Complete.

Transactions. 1900 to date. Complete.

Amsterdam. Koninklijke akademie van wetenschappen. Verhandelingen, 1854 to date. Complete.

Annali di mathematica, pura ed applicata. Milano, 1889 to date.

Annals of mathematics. 1884 to date. Complete.

Archiv der mathematik und physik. 1901 to date.

Berlin. Königlich-preussische akademie der wissenschaften. Mathematische und naturwissenschaftliche mittheilungen aus den sitzungsberichten. 1882-97. Complete.

Berliner mathematische gesellschaft. Sitzungsberichte. 1902 to date. Complete.

Bibliotheca mathematica. Stockholm, Berlin and Paris, 1884 to date. Complete.

Bologna, Istituto di. Reale academia delle scienze.

Commentarii. 1731-1791. Complete.

Novi commentarii. 1834-1849.

Memorie fis. e mat. 1806-1810.

Memorie. 1850 to date. Complete.

Boston. American academy of arts and sciences. Proceedings, 1870 to date. Complete.

British association for the advancement of science. Report. 1831 to date. Complete.

Brussels. Académie royale des sciences des lettres et des beaux-arts de Belgique.

Bulletins. Ser. 3. 1889 to date.

Mémoires couronnés et mémoires des savants étrangers. 1889-90.

Bulletin des sciences, mathématiques et astronomiques. 1870 to date. Complete.

Cambridge philosophical society.

Proceedings. 1843 to date. Complete.

Transactions. 1822 to date. Complete.

Colorado, University of. Studies. 1902 to date. Complete.

Deutsche mathematiker-vereinigung. Jahresbericht. Leipzig, 1890 to date. Complete.

Edinburgh philosophical journal. 1819-1826.

Edinburgh Royal Society. Transactions. 1783 to date. Complete.

Fortschritte der mathematik, Jahrbuch über die. Berlin, 1868 to date. Complete.

France, Société mathématique de. Bulletin. Paris, 1873 to date. Complete.

Göttingen. Königliche gesellschaft der wissenschaften. Nachrichten von der k. gesellschaft der wissenschaften und der Georg-Augusts-universität. 1853 to date.

Haarlem. Hollandsche maatschappij der wetenschappen. Archives néerlandaises des sciences exactes et naturelles. 1866 to date. Complete.

International catalogue of scientific literature. 1902 to date. Complete.

Internationale mathematiker-kongress. Verhandlungen. 1897 to date. Complete.

Journal de mathémetiques pures et appliquées. Paris, 1836 to date. Complete.

Journal für die reine und angewandte mathematik. Berlin, 1826 to date. Complete.

Leipzig. Königlich-sächsische gesellschaft der wissenchaften.

Berichte über die verhandlungen der mathematisch-physischen classe. 1849 to date. Complete.

Abhandlungen der mathematisch-physischen classe. 1852 to date. Complete.

Liége. Société royale des sciences. Mémoires. 1843 to date. Complete.

London mathematical society. Proceedings. 1865 to date. Complete.

London. Royal society.

Proceedings. 1800 to date. Complete.

Philosophical transactions. 1665 to date. Complete.

Mathematische annalen. Leipzig, 1869 to date. Complete.

Messenger of mathematics. Oxford, Cambridge and Dublin, 1862 to date. Complete.

Milan. Reale istituto lombardo di scienze e lettere.

Classe di scienze matematiche e naturali. Rendiconti. 1864-67. Complete.

Rendiconti. 1868 to date. Complete.

Memorie. 1843 to date. Complete.

Monatshefte für mathematik u. physik. Wien, 1908.

New York mathematical society. Bulletin. 1891-94. Complete.

Nouvelles annales de mathématiques. Paris, 1842 to date. Complete.

Paris. Institut de France. Académie des sciences. Comptes rendus hebdomadaires des séances. 1835 to date. Complete.

Paris. Annales scientifiques de l'école normale supèrieure. 1864 to date. Complete.

Paris. École polytechnique. Journal. 1794 to date. Complete.

Philosophical magazine. London, Edinburgh and Dublin, 1798 to date. Complete.

Quarterly journal of pure and applied mathematics. London, 1857 to date. Complete.

Revue semestrielle des publications mathématiques, rédigée sous les auspices de la société mathématique d'Amsterdam, 1893 to date. Complete.

Rome. Reale accademia dei lincei. Atti. Rendiconti.

Tokyo. Mathematico-physical society. Proceedings (Tôkyô sûgaku-buturigakkwai kizi) 2d Ser., 1901 to date. Complete.

Vienna. Kaiserliche akademie der wissenschaften. Sitzungsberichte der mathematisch-naturwissenschaftlichen classe. 1848 to date. Complete.

Zeitschrift für mathematik und physik. Leipzig, 1856 to date. Complete.

Zeitschrift für mathematische und naturwissenschaftliche unterricht. 1903 to date.

The mathematical department possesses a good collection of models, a Thomas arithmometer, and an Ammsler planimeter with revolving table.

DEPARTMENT OF PHYSICS

The Department of Physics of Clark University is exclusively a department for graduate study and research in pure and applied physics. In order to set forth to the intending student the facilities of this department, stress may be laid on a number of points in which it is believed that the conditions here are exceptional.

First, the fact that the attention of the professor is not distracted from the needs of the student by other duties, which, combined with the small number of students in the department enables an amount of personal attention to be given to each one which is, perhaps, unique in this country. The head of the department is able to see each student and to give him personal advice in the conduct of his researches or his studies every day if necessary. The facilities, without which no graduate department of research in physics can be complete, are comprised under three heads: first, a systematic course of lectures in theoretical or mathematical physics; second, a laboratory with a sufficient number of rooms for individual work and with a sufficient equipment of apparatus and an instrument shop for the speedy production of whatever may be necessary for the research in hand; third, a library containing the classic works on physics, with full sets of journals and proceedings of learned societies by which the history of progress, past and present, may be studied, and kept up-to-date by the continual purchase of the latest works. In all these directions the facilities offered by this department invite attention.

The lecture courses are so arranged as to cover in the cycle of two years all the principal subjects and methods of theoretical physics. The pursuit of them will enable the student to read and study with facility any memoirs on mathematical physics. The courses are so arranged that, although they follow in order, it is possible for a student to begin in either year of a cycle. Arrangements are now being made so that certain fundamental courses shall be delivered every year.

The Laboratory

The laboratory occupies three floors of one wing of a large, well lighted building free from disturbances, and admirably adapted to the purposes of a physical laboratory. On the ground floor is a room extending across the end of the building, forty-five feet long by twenty-two feet wide, with windows on three sides, above which are three similar rooms. A lift running from the bottom to the top floor affords a means of transporting apparatus, while its shaft furnishes space for manometer or barometer tubes. In the lower room are four piers with heavy stone tops, and two others below the floor on which can be placed heavy tables.

Also on the ground floor is a large dark room, partially below ground, in which the temperature is tolerably constant, containing a very large and heavy pier. The engine and storage-battery room contains a kerosene engine and dynamo on the same foundation and sixty storage cells of ten amperes capacity, constituting the power-supply. The engine may be started at a few moments' notice even at night. The storage cells are conveniently arranged so that each one is accessible from each side, from above and below, and the ventilation is excellent,

while the room is as light and clean as the work-rooms. Distributing switchboards allow the current from the dynamo or any section of the battery to be supplied to any of the rooms. On the same floor are three rooms constituting the workshop, one of the most important parts of a research department of physics. The first room is devoted to wood-working and pattern-making, and accommodates also a bench for soldering. The next room contains the machinist's bench, two engine-lathes and planer, and the third room a Rivett precision bench-lathe, jeweller's lathe and drill-press. There is no counter-shafting in the building, each tool being driven by a separate electric motor, while the capacity of the battery is such that for ordinary purposes it is not necessary to drive the engine for the shop alone, so that perfect quiet and steadiness are ensured. In the shop are executed all repairs and alterations of apparatus, and the new apparatus requiring continual experiment is constructed. Most of the principal pieces of apparatus belonging to this department have been thus constructed- In this manner, by having a mechanic always present, an extremely great economy in time and money is effected, and vexatious delays, which would otherwise completely arrest the progress of the work, are avoided. Facilities and encouragement are given to the students to construct apparatus for themselves.

On the main floor are the lecture room, the director's office, the large room used as the director's private laboratory and apparatus room, and three other convenient rooms for research. Two of these are arranged so that they may be darkened for photography, and are also fitted with chemical hoods. The large room on the top

floor is devoted to the Rowland twenty-foot diffraction grating, and has a photographic dark room attached. There has been constructed during the current year a storage-battery of two thousand small cells for researches requiring a constant source of high potential. This battery is conveniently housed next to the grating room. Every room in the laboratory contains sinks, gas and electric light connections, and several circuits connecting with the switchboard in the battery-room.

The laboratory is well equipped with apparatus for research, besides having the facilities above described for the construction of instruments of any sort needed for that purpose. In addition may be mentioned a large collection of diagrams illustrative of mathematical physics, many of them being originals of the figures in Professor Webster's "Electricity and Magnetism" and "Dynamics," and a number of interesting models used in teaching dynamics, thermodynamics, and electricity. Among them are Maxwell's Dynamical Top and a number of other interesting tops, Rayleigh's induction model, Gibbs's, van der Waals's and other thermodynamical surfaces. This collection of drawings and models can probably not be matched in this country, and is continually being increased.

The laboratory affords so much space that it is rarely necessary to put more than one student in a single room. Every student receives personal attention in the laboratory from the professor whenever he needs it, and is continually in receipt of instruction and suggestion by personal contact, the best form in which information can be imparted. Emphasis should be laid on the advantage to the research student of the contact with a professor who has no other duties or interests than the

furtherance of research, in an institution devoted to this as its main object.

Attention is called to the fact that so far as known, all members of this department who have stayed long enough to take a doctor's degree are in the occupation of positions, with few exceptions in colleges, in widely varied portions of the country, three members being at present professors in colleges in New York City. Several former members of the department have also gone into commercial work in the new field of wireless telegraphy, for which their work here had admirably fitted them while several others are occupying important positions in the U. S. Bureau of Standards.

Lectures

The courses of lectures offered follow, those which are not marked by a star being regular courses given in the cycle and constituting a course of from five to seven hours weekly, the starred courses being delivered at irregular intervals, according to the demands or the presence of students of sufficient advancement.

1. Dynamics. General Principles, Equations of Lagrange and Hamilton, Methods of Hamilton and Jacobi, Systems of Particles, Rigid Bodies.

This course is fundamental for the pursuit of all the others, and includes a detailed account of the principle of Least Action and the differential equations of Lagrange, preparatory to their application to other parts of mathematical physics such as optics and electricity.

2. Newtonian and Logarithmic Potential Functions, Attraction of Ellipsoids.

This course is a necessary preliminary to the study of electricity and magnetism, of hydrodynamics, and of the figure of the earth.

3. Elasticity, Hydrodynamics, Wave and Vortex Motion, Dynamical Basis of Sound and Light.

This course is the basis of applications of the theory of wave motion to sound, light, electro-magnetism, and earthquake waves, and to the study of meteorology.

3a*. Dynamics of Cyclic and Oscillatory Systems, with Applications to the Theory of Electricity, Sound and Light.

The substance of the preceding courses is contained in Professor Webster's Treatise on Dynamics, B. G. Teubner, Leipzig.

3b*. The Theory of Resonance with Applications to the Measurement of Sound and to Wireless Telegraphy.

This course takes up Professor Webster's original researches in acoustics, and also shows how the methods there employed bear on the fundamental electrical phonomena involved in wireless telegraphy.

4. Electricity and Magnetism. The Classical Theories and the Theory of Maxwell, with an Account of the Principal Methods for the Solution of Problems and Applications to Absolute Measurements.

The substance of this course is found in Professor Webster's Mathematical Treatise on the Theory of Electricity and Magnetism, London, Macmillan & Co.

4a*. Recent Developments in Electrical Theory, Including the Theory of Lorentz.

The application to the theory of Electrons and to the optics of bodies in motion.

5. The Theory of Light. Propagation of Light, Diffraction, Reflection and Refraction, Dispersion, Double Refraction, Polarization, Metallic Reflection, Magneto-Optics.

5a. Comparison of Theories of the Ether.

Critical and historical examination of the various mechanical explanations of the luminiferous ether, including those of Green, McCullagh, Kelvin, Maxwell, Sommerfeld and Larmor.

5b*. Geometrical Optics. Properties of Systems of Rays, and Their Various Aberrations. Hamilton's Characteristic Function or Eikonal. Applications to Optical Instruments.

6. Thermodynamics. Thermo- and Electro-Chemistry.

The establishment of the two laws of Thermodynamics, and their application, by means of the methods of Gibbs and Helmholtz, to the examination of physical and chemical phenomena. Application to heat-engines, including steam, gas, and oil engines, the flow of gases and vapors, and the steam turbine. The conditions of chemical equilibrium, phenomena of electrolysis, osmotic pressure, and capillarity.

7. The Kinetic Theory of Gases. The Maxwell-Boltzmann Theorem and the Elements of Statistical Mechanics.

8*. The Theory of Radiation and of a Black Body.

The relations obtained from the laws of Kirchhoff, Stefan, Wien, and Planck, by the recent application of Thermodynamics.

9*. The Phenomena of Conduction of Electricity in Gases, and of Radioactivity, and their Bearing on the Structure of the Atom.

10. The Partial Differential Equations of Mathematical Physics.

Laplace's Equation, Equation of Thermal and Electrical conduction, Equation of Wave-motion, Helmholtz's Equation, Beltrami-Lorentz Equation, Telegrapher's Equation, and their special cases; methods of Cauchy, Green and Riemann; Developments in Series, Fourier's Series, Legendre's, Laplace's, Bessel's and Lamé's functions.

This course is one of the most important for the physicist, and treats a great variety of subjects from the most varied fields, grouping them all into a connected system, and embracing all the methods of theoretical physics.

11*. The Elements of Integral Equations, and Their Application to Mathematical Physics.

12*. Selected Chapters in the Application of Theoretical Physics to Cosmical Phenomena, Including Problems in Geodesy, the Tides, Meteorology, Seismology, and Terrestrial Magnetism.

13*. Linear Differential Equations.

The applications of the theory of functions to the linear differential equations (ordinary) which arise in mathematical physics.

14*. Orthogonal Surfaces and Curvilinear Coordinates, and Their Applications.

15*. The theory of Elliptic Functions, with applications to Mechanics and Mathematical Physics.

The courses for 1909-10 are 5, 5a, 6, 7, 10. During the next year, 1, 2, 3, 4, 5b, 12 will be given.

In addition to the above formal courses there is held a weekly Colloquium, or meeting for the informal discussion of subjects not treated in the lectures, and for the presentation by the students of reports on important articles appearing in the journals. A part of the work of the colloquium consists in the systematic presentation of certain classical researches, more or less connected with the lectures, in preparing which the students make use of the original sources of information, thus gaining much acquaintance with the methods of the masters in research. The work of the colloquium has an excellent effect in training students to present their ideas in a systematic manner before an auditory.

The Library

Especial attention is called to the library facilities, in which Clark University has one of its strongest features. With a large separate building, administered in the most liberal manner with a view to the advantage of the research student, and with ample funds for the purchase of books, its facilities for the department of physics can hardly be surpassed even in the larger institutions. It may be said to contain all of the most important works in many languages and is continually kept up to date, any book wanted needing only to be mentioned to be procured. The library is particularly rich in journals, among which are included the transactions of the learned societies of England, France, Germany, Italy, Austria, Holland, and Belgium. There are few subjects connected with the study of physics which may not be thoroughly studied in this library. In the rare case of

journals not being found in this library, they may generally be had from the library of the American Academy of Arts and Sciences in Boston. Besides the usual abstracts and annual catalogues of papers, there is being compiled a card catalogue of titles in many fields of physics, which, as it grows in scope and becomes more complete, is becoming a most useful adjunct of the department.

DEPARTMENT OF CHEMISTRY

The aim of the Department is to equip students for original work in chemistry. Such equipment consisting in a clear knowledge of the principles and methods of the science, is believed to be best for the industrial chemist as well as for the collegiate teacher. The teacher of chemistry who is unable to contribute a share to the growth of his science will teach the dead letter of some text-book and can hardly impart to his students a practical knowledge of natural phenomena. And in the opinion of leaders of the great chemical industries in Europe, a young industrial chemist, too, is best equipped, not if he has acquired (necessarily unpractical) information in the chemistry of the manufactures, but if he has obtained clear critical knowledge of the principles of pure chemical science and some experience in grappling with difficulties. The desire for *such* knowledge, and the courage and perseverance necessary in attacking problems, are acquired only through research.

The work of the Department will be conducted with these principles in view and will be adjusted to the needs of the students from year to year. Advanced students will be expected to spend most of their time on research work. However, specialized courses on topics of history of chemistry, chemical dynamics, heterogeneous equilibria, organic synthesis, stereo-chemistry, electro- and thermo-chemistry, applications of thermodynamics to chemistry, etc., will be offered and the students will be expected to attend them regularly.

Each topic will be approached not as a chapter in a book but as a problem in nature. It will be introduced by an estimate of its importance and of its bearing on other problems. Then an account will be given, on the historical plan as far as possible, of the extent to which the problem has been solved, of how this was done, and of how much is not yet solved, with suggestions as to practical methods by which solution might be obtained. It is believed that such *critical mode* of study, much more than the "advanced" nature of the subjects studied, is the true characteristic of university work.

To aid students not quite prepared for work of this kind, lecture and laboratory courses will be offered in general inorganic and organic chemistry, organic synthesis and analysis, physical chemistry, etc. The time required for such students to qualify for the degree of Doctor of Philosophy will depend in each case upon the proficiency of the student. Residence for one year is required, and three years will not be too long for most graduates. A working knowledge of analytical geometry and the calculus will be pre-supposed in all the work of the Department.

The research work conducted in the Department will be mainly along the following lines: 1. Experimental and theoretical study of the deviations of fact from the accepted principles of general chemistry: 2. Experimental study of organic substances and reactions from the standpoint of chemical statics and dynamics.

Of course, promising investigations may be taken up, from time to time, along other lines as well.

Instead of more or less insignificant pieces of work being "assigned" to students for their first experience in research, they will be made, as early as possible, the

collaborators of their professor in his own investigations, unless, indeed, they bring forward practicable research projects of their own. Nothing could more certainly assure constant and intimate contact between professor and student and the student's really receiving the best that the Department can offer: individual guidance.

Requirements for the Doctor's Degree

1. A good reading knowledge of both German and French, which the student ought to acquire as early as possible.
2. A working knowledge of analytical geometry and the calculus.
3. The passing of an examination in the several branches of chemistry, including modern physical chemistry, chemical statics and chemical dynamics, and one minor subject, to be determined in each case by the head of the Chemical Department.
4. Above all, the presentation of a dissertation which in the opinion of the head of the Department will form a *genuine contribution*, either purely theoretical or experimental, to chemical science.

Courses

The lecture work this year is in a sense a continuation of last year's, and therefore a statement of both years' courses may not be devoid of interest.

The academic year 1908-09 was devoted mainly to studies in organic chemistry, by way of preparing a concrete basis for the present year's work in general and physical chemistry. This year the students have been advised to devote about one-quarter to one-third of their time to all scholastic work combined, and at least two-thirds of their time to original research. The scholastic work is mainly in general and physical chemistry, supplemented by an extensive course in thermodynamics given by Professor Webster in the Department of Physics. Parallel with these run briefer courses on

select chapters of modern organic and inorganic chemistry, with a small amount of laboratory work. Finally, in the Colloquium both students and instructors lecture on select topics of chemical research.

A. *Professor Rosanoff's Courses*

1. Organic Synthesis (laboratory course, given in 1908-09, with a few additional preparations to be carried out this year). Gattermann's *Praxis* is followed, with freqnent deviations, however, calculated to prevent the student from following directions like cook-book receipts, and to compel him to use his own inventive power.

2. Organic Stereo-Chemistry (given in 1908-09). This subject was chosen because presenting an opportunity for a thorough study of the carbohydrates, of the structure of benzine, of ethylene derivatives, etc.

3. The Hydro-Aromatic Series, including the monocyclic and polycyclic terpene bodies (given during the year 1908-09, to be followed by a course on open terpenes in 1910-11). This difficult chapter of recent organic chemistry was chosen, not only because a clear knowledge of it is becoming essential in the equipment of the best chemists, but also because it offers excellent opportunities for readings in the periodical literature of the last fifteen years.

4. General and Physical Chemistry, Tuesdays at 11 and Thursdays at 9 a. m. This course is given during the current year and will be followed by a special course on the thermodynamic method, its use and results in chemistry, in 1910-11. The main chapters of this year's course are as follows: (a) An almost exhaustive consideration of the laws of the gaseous state of aggregation and of the kinetic theory attempts of correlating the extant experimental data. A critical examination of the theory of corresponding states is naturally included in this chapter; (b) The known empirical relations between the physical properties of liquids (and solids) and their chemical composition and constitution, with detailed accounts of the experimental methods involved in determining those properties; (c) The theory of solutions, including a critical examination of the anomaly of strong electrolytes; (d) The general principles, methods,

and results of chemical statics and kinetics; (e) The fundamental principles of thermo- and electro-chemistry; (f) The Phase Rule, and a general introductory study of heterogeneous equilibria. The subject matter of the course is presented as a series of problems, partly solved, partly awaiting solution, and almost throughout calling for more experimental and mathematical investigation.

5. COLLOQUIUM, directed jointly by the members of the departmental staff. This is held once in two weeks, from 8 to 10 P. M., in the University Chemical Lecture-Room. The students are expected to report on such classical topics as the discovery of oxygen and the overthrow of the phlogiston theory, Pasteur's discovery of the stereoisomeric tartaric acids, etc.; or on recent contributions, such as typical Grignard syntheses, the reduction work of Sabatier and Senderens, the pyrogenetic researches of Ipatieff, new asymmetric syntheses, current contributions concerning the Walden inversion, recent work on the synthesis of alkaloids and of polypeptides, current studies of the kinetics and catalysis of organic reactions, etc. An important part of this year's colloquium work will consist in lectures by the students on the results of their own investigations.

B. *Dr. Merigold's Courses*

6. ADVANCED QUANTITATIVE ANALYSIS AND ORGANIC PREPARATIONS, given in 1908-09. This course is intended to give a more comprehensive view of the subject of quantitative analysis than is obtained from elementary courses. Lectures treat systematically the determination of all common bases and acids, with critical comparison of various methods. By discussion of the best methods introduced as a result of recent research, as well as of the best of the older methods, an attempt is made to make this feature of especial value. Attention is given to applications of modern theories, and some of the more complex methods of analysis are studied in the laboratory.

As a part of the laboratory work there is also given practice in the preparation of pure inorganic compounds. The methods used are not merely those commonly found in the text-books, but are based upon the most careful work to be found in the recent literature of inorganic research.

7. Advanced Inorganic Chemistry (given this year). A critical study of special topics of inorganic chemistry. This course is intended to furnish both theoretical and practical knowledge of some of the more important problems of inorganic chemistry. Special attention is given to the results of recent research upon such topics as the structure of atoms, valance and chemical affinity, stereo-chemistry of inorganic compounds, and the principles and methods of atomic weight determinations. A critical comparative study is made of the work of recent investigators in these subjects, and a bearing of this work upon present theories considered.

C. *Dr. Clark's Course*

8. Select Topics of Organic Chemistry (given this year), Fridays at 11 A. M. This course is intended to outline the recent advances made in some of the most important branches of present organic research, such as: the synthesis of alkaloids, Fisher's work on the proteins, a systematic study of the dyestuffs, including modern physical methods for determining the configuration of complex compounds, with special references to Baly's work on spectroscopy of organic compounds.

D. *Special Courses*

9. Dr. Hubbard, of the Department of Physics, is this year giving a course of lectures to the students of chemistry, interpreting and discussing the principles of thermo-dynamics as given in the mathematical course mentioned above.

10. In 1908-09, Professor Story lectured in the University Chemical Lecture-room on Mathematics for students of Chemistry. The aim of the course was to help the students acquire that mathematical knowledge, without which the professional education of a chemist, whether engaged in teaching or in industrial work, is to-day no longer complete.

E. *Professor Noyes's Lectures*

11. The Department has been fortunate enough to secure the appointment of Professor Arthur A. Noyes, of the Massachusetts Institute of Technology, as Non-resident University Lecturer on Chemical Research for the year 1910-11. The topics of Professor Noyes's lectures will be announced later.

Facilities

The University chemical laboratories occupy one wing, of the laboratory building. The storerooms contain an unusually large collection of organic preparations, besides all the ordinary inorganic chemicals. The collection of physico-chemical apparatus, including the latest form of Pulfrich's refractometer, an excellent Schmidt and Haensch polariscope, a fine spectroscope, a Burkhardt calculating machine, an Altschul apparatus for measuring critical pressures, specially constructed large constant-temperature stillheads, a set of excellent thermostats, sets of fine thermometers, etc., is sufficient for most ordinary purposes. Whatever special apparatus and chemicals are needed in connection with the work of research are ordered at once, every reasonable effort being made to help the student obtain a maximum of results with a minimum expenditure of time and energy. In this connection it may be mentioned that the Department is at liberty to use the services of the skilled mechanician regularly employed by the Department of Physics. Students will themselves prepare their chemicals, or build their research apparatus, only in those cases in which the Director may consider such work especially instructive to them.

It is believed that the facilities for serious research offered by the Department are in many ways exceptional.

Scholarships and Fellowships

The Department has at its disposal several Scholarships and Fellowships, which will be awarded each year to the ablest and best recommended applicants. Scholars, and especially Fellows, will co-operate with the

Director in maintaining a harmonious and scientific atmosphere in the Department and in promoting all the ends of the University. They will have no duties besides that of making the best use of the facilities for study and research offered to them.

The Library

The library of the Department contains complete files of all the more important chemical journals in English, German, and French. The collection of general works, monographs, and reference books is being rapidly enlarged. The productive endowment of the library is very large, and *all* books needed are procured at once.

Researches carried on in the Department of Chemistry since the Installation of its Present Head, September, 1907

1. Practical elaboration of a new method for determining the partial vapor pressures of organic mixtures, and determination by means of it of the vapor pressures of a number of typical binary mixtures (published in the Journal of the Am. Chem. Soc., for September, 1909, and in the *Zeit. physik. Chem.*, v. 68, pp. 641-683. See also Journal of the Am. Chem. Soc., for April, 1908, and Zeitschrift fur physikalische Chemie, v. 66, p. 349).

2. A quantative study of the Victory Meyer Esterification Law and the Steric Hindrance hypothesis (published in the Journal of the Am. Chem. Soc., for Dec., 1908, and in the Zeitschrift fur physikalische Chemie).

3. A quantitative study of steric hindrances in the esterification of fatty acids (published in the Journal of the Am. Chem. Soc., for Dec., 1908, and in the Zeitschrift fur physiklalische Chemie).

4. Perfection of a precise and rapid method for determining halogens in organic compounds (published in the Journal of the Am. Chem. Soc., for Jan., 1909, and in the "Chemical News" of London).

5. A study of the transformation of aldohexoses into alcohol by ferments, enzymes, and alkalies (uncompleted).

6. A new relationship between the vapor pressures of binary mixtures and a general quantitative theory of fractional distillation (nearly ready for publication).

7. Experimental study of fractional distillation in the light of the results of the preceding research (in progress).

8. A theoretical study of the variation of the vapor composition of binary mixtures with the temperature, furnishing a complete solution of its problem (ready for publication).

9. A study of the mechanism of iodination in the aromatic series by halogen carriers (uncompleted).

10. A new study of steric hindrances in esterification (in progress).

11. A precise quantitative study of the phenomena of direct esterification and ester hydrolysis (in progress).

12. A study of the kinetics of certain inorganic reactions (temporarily interrupted).

13. A precise study of the decomposition of tertiary amyl acetate (in progress).

14. A peculiar transformation of benzo-bromamide (in progress).

15. A study of the preparation of acetamide (in progress).

16. On the Definition of an Ideal Gas (published in the Physical Review, v. 29, p. 304).

17. A new study of the Duhem-Margules equation (nearly ready for publication).

18. A theoretical revision of some of the principles of the theory of solutions (in progress).

19. A new study of the dynamics of sugar inversion (in progress).

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Clark University

DIVISION OF EXACT SCIENCES

DEPARTMENTS OF MATHEMATICS
PHYSICS AND CHEMISTRY

1911

WORCESTER, MASSACHUSETTS

CALENDAR 1911-1912

1911		
April 3	Monday	Spring Recess
April 8	Saturday	
April 19	Wednesday	Patriots' Day
May 30	Tuesday	Memorial Day
June 15	Thursday	Twenty-second academic year closes

Summer Vacation of 14 Weeks

Sept. 21	Thursday	Twenty-third academic year begins
Nov. 30	Thursday	Thanksgiving Day
Dec. 20	Wednesday	Christmas Recess
1912		
Jan. 2	Tuesday	
Feb. 1	Thursday	Founder's Day*
Feb. 22	Thursday	Washington's Birthday
April 1	Monday	Spring Recess
April 6	Saturday	
April 19	Friday	Patriots' Day
May 30	Thursday	Memorial Day
June 20	Thursday	Twenty-third academic year closes

*Not a holiday

Clark University

Worcester, Massachusetts

Division of Exact Sciences

DEPARTMENTS OF MATHEMATICS, PHYSICS AND CHEMISTRY

G. Stanley Hall, Ph.D., LL. D.
President of the University

Henry Taber, Ph.D.
Chairman of the Division

J. C. Hubbard, Ph.D.
Secretary of the Division

DEPARTMENT OF MATHEMATICS

William Edward Story, Ph.D.
Professor of Mathematics

A. B., Harvard University, 1871; Parker Fellow, 1874-75; Student, Universities of Berlin and Leipzig, 1871-75; Ph.D., Leipzig, 1875; Tutor of Mathematics, Harvard University, 1875-76; Associate, Assistant Professor and Associate Professor of Mathematics, Johns Hopkins University, 1876-89; Professor of Mathematics, Clark University, 1889-; Professor of Mathematics, Clark College, 1902-07; Member of the National Academy of Sciences; Member of the London Mathematical Society and of the American Mathematical Society; Resident Fellow of the American Academy of Arts and Sciences; Fellow of the American Association for the Advancement of Science.

Henry Taber, Ph.D.
Professor of Mathematics

Ph.B., Yale University, 1882; Ph.D., Johns Hopkins University, 1888; Assistant in Mathematics, Johns Hopkins University, 1888-89; Docent in Mathematics, Clark University, 1889-92; Assistant Professor, 1892-1903; Professor, 1903-; Member of the London Mathematical Society; Member of the Deutsche Mathematische Vereinigung; Member of the American Mathematical Society; Resident Fellow of the American Academy of Arts and Sciences.

JOSEPH DE PEROTT

Lecturer in Mathematics

Student, Universities of Paris and Berlin, 1877-80; Docent in Mathematics, Clark University, 1890-1904; Lecturer 1904-.

FRANK B. WILLIAMS, PH.D.

Instructor in Mathematics and Collegiate Professor of Mathematics

C. E., Missouri State University, 1890; Teaching Fellow in Mathematics, 1892-93; M.S., 1893; Scholar in Mathematics, Clark University, 1897-98; Fellow, 1898-1900; Ph.D., 1900; Assistant Professor of Mathematics, Union College, 1900-07; Assistant Professor of Mathematics, Clark College, 1907-08; Professor of Mathematics, Clark College, 1908-; Instructor in Mathematics, Clark University, 1910—;Fellow of the American Association for the Advancement of Science.

DEPARTMENT OF PHYSICS

ARTHUR GORDON WEBSTER, PH.D., D.SC., LL. D.

Professor of Physics and Director of the Physical Laboratories

A.B., Harvard University, 1885; Instructor in Mathematics, Harvard University, 1885-86; Parker Fellow, 1886-89; Student, Universities of Berlin, Paris, Stockholm, 1886-90; Ph.D., Berlin, 1890; Docent in Physics, Clark University, 1890-92; Assistant Professor, 1892-1900; Professor, 1900-; Professor of Physics, Clark College, 1902-07; D.Sc., Tufts College, 1905; LL.D., Hobart College, 1908; Member of National Academy of Sciences; Member American Philosophical Society; President, 1903-05 American Physical Society; Resident Fellow of the American Academy of Arts and Sciences; Fellow, American Association for the Advancement of Science; Member American Mathematical Society, Deutsche Mathematiker-Vereinigung, Circolo Matematico di Palermo.

JOHN CHARLES HUBBARD, PH.D.

Instructor in Physics and Collegiate Assistant Professor of Physics

B.S., University of Colorado, 1901; Scholar in Physics, Clark University, and Assistant to Professor Webster, 1901-02; Fellow, 1902-04; Ph.D., Clark University, 1904; Honorary Fellow, *ibid.*, 1906-09; Instructor, 1909-; Instructor in Physics, Simmons College, 1904-05; Assistant Professor of Physics, and Secretary of the Faculty of Applied Science, New York University, 1905-06; Assistant Professor of Physics, Clark College, 1906-; Member American Physical Society; Fellow of the American Association for the Advancement of Science.

THOMAS LANSING PORTER, PH.D.

Research Assistant to Professor Webster

B. S., Northwestern University, 1907; Laboratory Assistant in Physics, *ibid.*, 1906-07; Research Assistant to Professor Webster, Clark University, 1907-08, 1909—; A. M., Clark University, 1908; Honorary Fellow, *ibid.*, 1908-09; Instructor in Physics, Clark College 1908-09; Ph. D., Clark University, 1910; Associate Member of American Physical Society.

CHARLES WITTIG

Mechanician

DEPARTMENT OF CHEMISTRY

MARTIN A. ROSANOFF, SC.D.

Assistant Professor of Chemistry and Director of the Chemical Laboratories

Ph. B., New York University, 1895; Sc. D., 1908; Student, University of Berlin, 1895-96; Research Laboratory of Organic Chemistry, University of Paris, 1896-98; Research Assistant to Dr. J. M. Crafts, Boston, Mass., 1898-99; Research Fellow, New York University, 1899-1900; Editor for Exact Science in the New International Encyclopædia, 1900-03; Research Assistant to Mr. Thomas A. Edison, Orange, N.J., 1903-04; Instructor in Theoretical Chemistry, New York University, 1904-05; Assistant Professor of Chemistry, 1905-07; Head of the Chemical Department with the title of Assistant Professor of Chemistry, Clark University, and Assistant Professor of Organic Chemistry, Clark College, 1907-09; Professor, 1910–; Fellow of the American Association for the Advancement of Science; Nichols Medalist of the American Chemical Society.

BENJAMIN S. MERIGOLD, PH.D.

Instructor in Chemistry and Collegiate Professor of Chemistry

A. B., Harvard University, 1896; A. M., 1897; Ph.D., 1901; Assistant in Chemistry, Harvard University, 1896-1900; Instructor in Chemistry, Worcester Polytechnic Institute, 1900-03; Assistant Professor of Chemistry, Clark College, 1903–08; Professor, 1908–; Instructor in Chemistry, Clark University, 1905–.

ROBERT HARVEY CLARK, PH.D.

Docent in Chemistry and Collegiate Assistant Professor of Chemistry

A.B., University of Toronto, 1905; A. M., 1906; Ph. D., University of Leipzig, 1908; Assistant in Chemistry, University of Toronto, 1905-06; 1851 Exhibition Science Research Scholar, University of Leipzig, 1906-09; Acting Assistant Professor of Chemistry, Clark College, 1909-10; Assistant Professor, 1910-.

NON-RESIDENT UNIVERSITY LECTURERS

ARTHUR A. NOYES, PH.D., SC.D, LL. D.

Non-resident University Lecturer in Chemical Research

Professor of Theoretical Chemistry, Director of the Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

GEORGE A. HULETT, PH.D.

Non-resident University Lecturer in Electro-chemical Research

Professor of Physical Chemistry in Princeton University.

ROBERT KENNEDY DUNCAN

Non-resident University Lecturer in Industrial Chemical Research

Director of Industrial Research and Professor of Industrial Chemistry at the University of Pittsburgh, and at the University of Kansas.

GENERAL STATEMENT

Clark University was established in the City of Worcester in 1889. The object of the University is to promote scientific research and to provide by suitable instruction and guidance a foundation of knowledge and experience for those desiring to become specialists and teachers in higher institutions of learning. The number of departments has been purposely limited. It has been from the beginning the settled policy of the institution to first strengthen departments already established until they are as thorough, as advanced, as special, and as efficient as possible, before proceeding to the establishment of new ones.

Several thousand memoirs and many books have been published by members of the University since its establishment and the former students, numbering nearly a thousand, are scattered over the country in university and college work, many of them occupying positions of high rank.

The University now consists of nine departments, as follows:

I. Mathematics
II. Physics
III. Chemistry
IV. Biology
V. Anthropology
VI. Psychology
VII. Pedagogy
VIII. Economics and Sociology
IX. History

For the purpose of better correlating instruction and of securing closer personal supervision of the work of students, the departments of Mathematics, Physics, and Chemistry have been organized into a Division of Exact Sciences.

The Advantages Offered by the University

The most prominent feature of Clark University is *the close relationship of the instructors and investigators in the several departments with their students.* The staff is large in comparison with the number of men taking instruction and doing research, and most of the University staff have no connection with collegiate teaching, the burden of professors in most American universities. The whole time of the professor is thus available for a comparatively small number of students, and it becomes possible for him to know intimately the needs and capacity of each; the individual guidance by and contact with men of recognized attainments thus secured enhancing efficiency and stimulating zeal to a degree which would be impossible in a large institution. Too much cannot be said of a system which places the beginner in such close relationship with an investigator that he can see science in the making from the beginning of his University career.

Seminaries or colloquia are held regularly in each of the departments, at which each student is expected from time to time to take part, presenting results of his own work or reports of classical or recent experimental or theoretical work. This exericse is invaluable in training the student to present ideas and to think clearly before a critical audience.

In connection with the Division of Exact Sciences has been carried on a study of methods and aims and the needs of students. It is believed that the results will secure for students the most effective programmes according to their various purposes.

Arrangements are made each year for securing a number of eminent men of science as non-resident lecturers. These men will visit the University from time to time and present

the newest results and developments in their own special fields.

Worthy of mention is the relationship of the work of the University to that of Clark College, an institution having a a separate endowment, classrooms, laboratories and library and its own president and faculty. The University and College are thus enabled to concentrate upon the problems peculiar to the sphere of each, and yet to receive mutual benefit. Men coming to the University who feel a need of further preparation for their work have an opportunity of receiving instruction in collegiate courses.

The scientific laboratories of Clark University are supported by ample annual appropriations, which enable each department to carry on efficiently any desired research. The University conducts a well appointed shop in which many of the instruments required are constructed, and where repairs and alterations may be quickly made. The laboratories are large and pleasant and afford space and facilities for many lines of research.

The library is growing rapidly and contains valuable sets of periodicals and is notably complete in the lines of work represented by the existing departments. The reading room receives over 500 journals. A list of those bearing upon the work of the departments of this Division will be found at the end of this circular. The administration of the library is unique in its helpfulness and liberality. The need of a book has only to be mentioned, and the book is secured. There is no limit to the number of books which may be withdrawn, and there is no limit to the time which each book may be kept, consistent with the needs of others. Every member of the University has direct access to each book and journal. Card indexes of titles are being prepared under the supervision of members of the Division. These are already very complete in many lines of research and are proving

a valuable supplement to the usual monthly and annual lists issued by the journals.

The location of the University in a cosmopolitan city of 150,000 people, and within an hour's ride from Boston, secures for its members easy access to music and art and to the notable museums and libraries in this region. The Worcester Art Museum is one of the best endowed in this country. In this city are the Library of the American Antiquarian Society, organized in 1812, and containing over 120,000 volumes, and the Worcester Public Library, receiving 600 newspapers and magazines containing 165,000 volumes, both free to members of the University. A system of exchange enables students to secure books from the American Academy of Arts and Sciences in Boston, and from Harvard University.

ADMISSION

Only graduate students are admitted, or those of equivalent attainments. At present, no entrance examinations are required, but, by testimonials, diplomas, or personal interviews the authorities must be satisfied that the applicant has scholarship enough to work to advantage.

Candidates for Degrees

The University confers two degrees, the degree of Doctor of Philosophy, and the degree of Master of Arts.

The degree of *Doctor of Philosophy* requires at least one year, but in most cases two or three years, of residence in graduate work, and is given when the candidate shall have satisfied the authorities by suitable examination and by the preparation of a dissertation embodying the results of original investigation that he possesses fitness for the degree.

The degree of *Master of Arts* is conferred upon a candidate who has spent one year in graduate study and who has satis-

fied the authorities by suitable examination and the preparation of a thesis that he possesses fitness for the degree. The selection of studies may be such as to be preliminary for teaching, preparation for professional study, technical work, or a tentative beginning for the doctorate, or for purely cultural purposes; and candidates are encouraged to choose such studies as may accomplish their ends as effectively and definitely as possible. Candidates may choose any courses offered by the University, provided they are prepared to pursue such courses with profit. The courses in the departments constituting this division and in the department of Pedagogy afford special training for those who wish to become teachers of science.

Special Students

In addition to candidates for degrees the University will receive students who wish to pursue some approved line of research and whose attainments are such as to satisfy the requirements of the University, but who do not care to matriculate or become candidates for a degree. Such students may be allowed entire freedom in their choice of studies and may enjoy all the privileges of the University.

Fellowships and Scholarships

Fellowships and scholarships at Clark University are intended to aid young men and women of promise who desire to pursue post-graduate studies in order to fit themselves for intellectual careers. There are no duties attached to these positions aside from making the best use of the facilities of the University for study and research. It is desirable, but not required, that candidates for fellowships should intend to proceed to the degree of Doctor of Philosophy or to equivalent attainments.

No application blanks are provided, but it is desired that the candidate should state fully and in writing his previous course of study and submit testimonials or diplomas, especially such as indicate a decided preference for some particular department. These should be accompanied also, if practicable, by some specimen of the candidate's work. Applications will be considered in May and in October and should be in the hands of the President early in the former month or before the first day of the latter. In special cases vacancies may be filled by appointments at any time during the year. The names of unsuccessful candidates will not be made public.

Fees

Students not holding fellowships or scholarships are expected to pay a fee of $100 per annum. Exception is made in the case of graduates of Clark College, and of other Worcester Institutions of collegiate grade, from whom no fee is required.

Board and Rooms

Clark College conducts a dining hall, all the privileges of which are open to the students of the University. Excellent board is given for four dollars weekly. Board at other rates may be secured outside. All possible aid is given in securing board and rooms for students. Rooms vary from one dollar weekly up, according to location and conveniences.

Information

Intending students and others interested in Mathematics, Physics or Chemistry are invited to address inquiries relating to admission, fellowships or scholarships, or general information, to the Secretary of the Division, J. C. Hubbard, Clark University, Worcester, Mass.

I. MATHEMATICS

Programme for 1911-1912

Instruction in Mathematics

The chief aim of the department is to make independent investigators of such students as have mathematical taste and ability; these naturally look forward to careers as teachers of the higher mathematics in colleges and universities, and we believe that the course of training best adapted to the development of investigators is also that which is most suitable for all who would be efficient college professors, even if they are not ambitious to engage in research. The first essential of success in either of these lines is the habit of mathematical thought, and the direct object of our instruction is the acquisition of this habit by each of our students. With this end in view, we expect every student to make himself familiar with the general methods and most salient results of a large number of different branches of mathematics, conversant with the detailed results and the literature of a few branches, and thorough master of at least one special topic to the extent of making a real contribution to our knowledge of that subject.

In accordance with these principles, the instruction is given by means of introductory, advanced, and special courses of lectures, seminaries, and personal guidance in reading and investigation.

The introductory courses (mostly given in alternate years) treat the following subjects:

Analytic Geometry of Conics, Higher Plane Curves, Quadrics, Higher Surfaces, and Twisted Curves; 5 hours a week, through the year.

DIFFERENTIAL EQUATIONS, AND CALCULUS OF VARIATIONS; 5 hours a week, through the year.

THEORY OF FUNCTIONS OF REAL AND IMAGINARY VARIABLES, ELLIPTIC FUNCTIONS, AND DEFINITE INTEGRALS; 5 hours a week, through the year.

THEORY OF NUMBERS; 2 hours a week, one half-year.

MODERN SYNTHETIC GEOMETRY; 2 hours a week, one half-year.

ALGEBRAIC SUBSTITUTIONS AND THEIR APPLICATION TO THE THEORY OF EQUATIONS; 2 hours a week, one half-year.

ALGEBRAIC INVARIANTS; 2 hours a week, one half-year.

FINITE DIFFERENCES; 2 hours a week, one half-year.

It is expected that every student will take each course in the earliest year of his residence in which it is given, unless he has already completed an equivalent course elsewhere. The chief object of these courses is to make the student familiar with the various methods of mathematical research and the concepts of mathematical thought at the present day. Thus, for example, curves and surfaces are treated by modern methods from the beginning, with adequate consideration of the discoveries of the great geometers of recent times. The usual college courses in the theory of algebraic equations, analytic geometry, and the differential and integral calculus furnish all the necessary preparation for these introductory courses, although it is very desirable that the student be acquainted with the properties of determinants and their application to the solution of linear equations, and with the methods of solving differential equations of the simpler types. Deficiencies in these subjects may be made up by attendance on the corresponding courses in the Collegiate Department of the University.

Special advanced courses, open to all who are prepared for them, are given annually in subjects varying with the interests of the instructors and the needs of the students. These advanced courses are not repeated at regular intervals, but properly prepared students will receive the personal assistance of one or other of the instructors in reading any

subject not announced for the year in which they desire to take it.

The number and scope of the advanced courses given each year have been, thus far, regulated by the number of students qualified to profit by them and by the individual interests of the instructors; these courses will be increased, both in number and variety, whenever a real demand for such an increase shall make itself apparent. While the present purely scientific character of the University precludes instruction in strictly technical branches, we hope that the time is not far distant when the demand shall make it advisable, and increased facilities shall make it possible, to announce courses in Descriptive Geometry, Graphical Statics, Mathematical Astronomy, Vital Probabilities, and all the more important applications of mathematics to other sciences and to technical subjects. The applications of mathematics to physics already receive adequate consideration, and the further extension of such applications awaits only a demand for it on the part of students.

The subjects in which advanced courses may be expected to be given every few years include the following:

History of Mathematics:

Arithemtic: Numerical computations; Theory of numbers; Finite differences and the Calculus of operations; Probabilities and the Theory or errors.

Algebra: Substitution-groups and the Galois theory of equations; Invariants; Quadratic forms; Simultaneous equations (including Restricted systems); Multiple algebra.

Higher Analysis: Differential equations, ordinary and partial; Continuous groups; Definite integrals and Fourier's series.

Theory of Functions: Functions of real and complex variables; Point-aggregates; Elliptic functions; Abelian integrals.

Geometry: Modern synthetic geometry; Analytic geometry of higher plane curves, higher surfaces, and twisted curves; Rational and uniform transformations of curves and surfaces; Infinitesimal geometry; Analysis situs; Quaternions.

Symbolic Logic.

Other courses will be given whenever there is a demand for them, as in the past. The instructors are always glad to assist students in any line of mathematics that falls within the range of their own studies. The small number of students makes it possible to give personal attention to individuals, and the intimate and confidential relation thus established between pupil and teacher is an advantage that cannot be overestimated and ought not to be left out of account by the prospective student in determining where his studies shall be pursued.

For the academic year 1911–12, the following courses of lectures are announced:

BY PROFESSOR STORY

Introductory Course:

ANALYTIC GEOMETRY OF HIGHER PLANE CURVES, HIGHER SURFACES, AND TWISTED CURVES; 3 hours a week through the year.

Advanced Courses:

HISTORY OF MATHEMATICS; 2 hours a week, first half-year.

HYPERSPACE AND NON-EUCLIDIAN GEOMETRY; 2 hours a week, through the year.

ALGEBRAIC INVARIANTS; 2 hours a week, second half-year.

SEMINARY FOR ADVANCED STUDENTS; through the year.

BY PROFESSOR TABER

Introductory Course:

DIFFERENTIAL EQUATIONS AND CALCULUS OF VARIATIONS; 5 hours a week, through the year.

Advanced Courses:

TRANSFORMATION GROUPS; 2 hours a week, first half-year.

PICARD-VESSIOT THEORY OF LINEAR DIFFERENTIAL EQUATIONS; 2 hours a week, second half-year.

SEMINARY, through the year.

BY PROFESSOR WEBSTER

[See announcement of Department of Physics, courses 10, 11, 13, 14.]

BY M. DE PEROTT

Introductory Course:

THEORY OF NUMBERS; 2 hours a week, first half-year.

ADVANCED COURSE:

ALGEBRAIC SUBSTITUTIONS; 2 hours a week, second half-year.

BY DR. WILLIAMS

Introductory Course:

CONIC SECTIONS AND QUADRIC SURFACES (Modern methods, homogeneous coördinates, etc.); 2 hours a week, through the year.

While desirous of supplying all possible facilities to those who wish to pursue studies in special branches, and to those who, already occupying permanent positions, have but a limited leave of absence, we have made it our chief object to provide a thorough training for those who, having just completed a college course, have not yet entered upon their life-work. This provision consists of such courses of lectures, seminaries, and individual assistance as should enable a faithful student endowed with the proper natural ability to satisfy the requirements for the degree of Doctor of Philosophy at the end of his third year with us. The requirements for this degree have been determined by our conception of the ideal teacher, as already stated. To acquire the necessary breadth of knowledge of mathematics as a whole, the candidate is expected to attend, during his first two years, specified introductory courses of lectures on the general principles, methods, and results of all the more important branches of pure mathematics, to supplement these lectures by private reading and to take an active part in the seminary. In the seminary, a special topic more or less directly connected with the subject of some lecture, is assigned, from time to time, to each student, who is required to read it up and make an oral report upon it before the class. Each candidate for the Doctor's

degree is expected to attend a number of advanced courses. He spends the greater part of his third year in the original investigation, under the constant personal guidance of one of the instructors, of a topic of his own selection. In preparing for this investigation he is required to make a practically complete bibliography of the subject and to read all the more important available articles that have been written on it. The results of the investigation, embodied in a dissertation suitable for printing, must be submitted to the instructor under whose direction the work was done, and must receive his approval before the candidate will be admitted to the final examination for the degree. This approval will not be given unless the dissertation is satisfactory in form and completeness and the results are sufficiently novel and important to constitute a real contribution to science. The dissertation is, in fact, the main criterion by which the candidate is judged, and no amount of other work will compensate for its defects.

Each of the instructors is engaged in research and has always a number of investigations planned for himself, which have often been carried to a well advanced stage but are not completed for want of time. Such incomplete investigations are given to properly prepared candidates for the Doctor's degree, and they receive from the instructor all the assistance necessary for the completion of the work, thus becoming, to a certain extent, collaborateurs with the instructor.

The preparation of a bibliography of any topic is greatly facilitated by a classified index of mathematical literature on the card-catalogue plan, which has been prepared under the supervision of Professor Story and now includes nearly one hundred thousand titles of periodical articles, separate memoirs, and books in all fields of pure mathematics. This index is much more complete than the Royal Society's

catalogue, even in the restricted field of that catalogue (periodicals published between 1800 and 1900), and will be extended as rapidly as possible.

The ability of our graduates to carry on research and the excellence of the work actually done is assured by the regulation that each dissertation accepted by us as worthy of the degree shall be printed with the explicit approval of a member of our Faculty. It is evident that, whereas any one that has the necessary preparation and taste for mathematics may profit by the advantages here afforded, only those who have a certain amount of mathematical genius can secure the degree.

In making appointments to fellowships and scholarships we have endeavored to maintain the same high standard. We are on the lookout for mathematical geniuses; but it is difficult to determine from the evidence of others whether candidates come up to our standard or not; so that we have adopted the general policy of giving the best appointments to those only that have been with us for at least one year, and about whom we are in position to judge for ourselves. Of course, this policy could not be carried out during the earlier years of the University, and its effect is apparent in the fact that, whereas seventy-five per cent of the students that entered the mathematical department during the first three years remained with us but one year, only thirty-three per cent. of those that have been admitted during the years 1892-1910 left at the end of their first year. We do not mean to imply that those who left before completing our course were inferior in ability to those who remained three years, but we desire particularly to encourage men who can and will go forward to the degree.

Nearly all of those who have studied mathematics with us have adopted teaching as a profession, sixty-eight per cent are now members of college faculties, and thirteen per

cent are engaged in higher school work. Those who have received the doctor's degree have generally secured at once desirable positions in which to begin their life-work, and most of them have already acquired for themselves, by distinguished ability, very decided influence in the institutions with which they are connected.

The degree of Master of Arts will be conferred upon students who complete with credit an approved course of one year and present a satisfactory thesis.

Every facility for the study of special branches will be given to properly prepared students who are not candidates for a degree, as also to those who, having already attained to the Doctor's degree (here or elsewhere), wish to continue mathematical study or investigation.

Material Facilities

The library is provided with the more important text-books, treatises, and memoirs on the various branches of mathematics, as well as the principal journals and transactions of learned societies that are devoted to any considerable extent to mathematics. A list of these journals will be found at the end of this circular.

The mathematical department possesses a good collection of models, a Thomas arithmometer, and an Ammsler planimeter with revolving table.

II PHYSICS

The Department of Physics of Clark University is exclusively a department for graduate study and research in pure and applied physics. In order to set forth to the intending student the facilities of this department, stress may be laid on a number of points in which it is believed that the conditions here are exceptional.

First, the fact that the attention of the professor is not distracted from the needs of the student by other duties, which, combined with the small number of students in the department enables an amount of personal attention to be given to each one which is, perhaps unique in this country. The head of the department is able to see each student and to give him personal advice in the conduct of his researches or his studies every day if necessary. The facilities, without which no graduate department of research in physics can be complete, are comprised under three heads: first, a systematic course of lectures in theoretical or mathematical physics; second, a laboratory with a sufficient number of rooms for individual work and with a sufficient equipment of apparatus and an instrument shop for the speedy production of whatever may be necessary for the research in hand; third, a library containing the classic works on physics, with full sets of journals and proceedings of learned societies by which the history of progress, past and present, may be studied, and kept up-to-date by the continual purchase of the latest works. In all these directions the facilities offered by this department invite attention.

The lecture courses are so arranged as to cover in a cycle of two years all the principal subjects and methods of theoretical physics. The pursuit of them will fit the student to

read and study with facility any memoirs on mathematical physics. The courses are so arranged that, although they follow in order, it is possible for a student to begin in either year of the cycle. The regular courses are those not marked with a star, and constitute a course of from five to seven hours weekly. The starred courses are delivered at irregular intervals, according to the demands or the presence of students of sufficient advancement.

LECTURES

1. Dynamics. General Principles, Equations of Lagrange and Hamilton, Methods of Hamilton and Jacobi, Systems of Particles, Rigid Bodies.

This course is fundamental for the pursuit of all the others, and includes a detailed account of the principle of Least Action and the differential equations of Lagrange, preparatory to their application to other parts of mathematical physics such as optics and electricity.

2. Newtonian and Logarithmic Potential Functions, Attraction of Ellipsoids.

This course is a necessary preliminary to the study of electricity and magnetism, of hydrodynamics, and of the figure of the earth.

3. Elasticity, Hydrodynamics, Wave and Vortex Motion, Dynamical Basis of Sound and Light.

This course is the basis of applications of the theory of wave motion to sound, light, electro-magnetism, and earthquake waves, and to the study of meteorology.

3a. * Dynamics of Cyclic and Oscillatory Systems, with Applications to the Theory of Electricity, Sound and Light.

The substance of the preceding courses is contained in Professor Webster's Treatise on Dynamics, B. G. Teubner, Leipzig.

3b. * The Theory of Resonance with Applications to the Measurement of Sound and to Wireless Telegraphy.

This course takes up Professor Webster's original researches in acoustics, and also shows how the methods there employed bear on the fundamental electrical phenomena involved in wireless telegraphy.

4. Electricity and Magnetism. The Classical Theories and the Theory of Maxwell, with an account of the principal methods for the solution of problems and applications to absolute measurements.

The substance of this course is found in Professor Webster's Mathematical Treatise on the Theory of Electricity and Magnetism, London, Macmillan & Co.

4a. * Recent Developments in Electrical Theory, including the Theory of Lorentz and the Principle of Relativety.

The application to the theory of electrons and to the optics of bodies in motion.

5. The Theory of Light. Propagation of Light, Diffraction, Reflection and Refraction, Dispersion, Double Refraction, Polarization, Metallic Reflection, Magneto-optics.

5a. * Comparison of Theories of the Ether.

Critical and historical examination of the various mechanical explanations of the luminiferous ether, including those of Green, McCullagh, Kelvin, Maxwell, Sommerfeld and Larmor.

5b. * Geometrical Optics. Properties of Systems of Rays, and their Various Aberrations. Hamilton's Characteristic Function or Eikonal. Applications to Optical Instruments.

6. Thermodynamics. Thermo- and Electro-Chemistry.

The establishment of the two laws of thermodynamics, and their application, by means of the methods of Gibbs and Helmholtz, to the examination of physical and chemical phenomena. Application to heat-engines, including steam, gas, and oil engines, the flow of gases and vapors, and the steam turbine. The conditions of chemical equilibrium, phenomena of electrolysis, osmotic pressure, and capillarity.

7. The Kinetic Theory of Gases. The Maxwell-Boltzmann Theorem and the Elements of Statistical Mechanics.

8. * The Theory of Radiation and of a Black Body.

The relations obtained from the laws of Kirchhoff, Stefan, Wien, and Planck, by the recent applications of thermodynamics.

9. * The Phenomena of Conduction of Electricity in Gases, and of Radioactivity, and their Bearing on the Structure of the Atom.

10. The Partial Differential Equations of Mathematical Physics.

Laplace's Equation, Equation of Thermal and Electrical Conduction, Equation of Wave-motion, Helmholtz's Equation, Beltrami-Lorentz Equation, Telegrapher's Equation, and their special cases; methods of Cauchy, Green and Riemann; Normal functions, Developments in Series, Fourier's Series, Legendre's, Laplace's, Bessel's and Lamé's functions.

This course is one of the most important for the physicist, and treats a great variety of subjects from the most varied fields, grouping them all into a connected system, and embracing all the methods of theoretical physics.

11.* The Elements of Integral Equations, and their application to Mathematical Physics.

12.* Selected Chapters in the Application of Theoretical Physics to Cosmical Phenomena. including Problems in Geodesy, the Tides, Meteorology, Seismology, and Terrestrial Magnetism.

13.* Linear Differential Equations.

The applications of the theory of functions to the linear differential equations of the second order which arise in mathematical physics.

14.* Orthogonal Surfaces and Curvilinear Coördinates and their Applications.

The courses for 1911-12 will be 5, 5a, 6, 7, 8, 10. During the past year 1, 2, 3, 3*b*, 4, 12, have been given.

Course 2 has this year been given by Dr. Hubbard, while Dr. T. L. Porter has at various times given part of the lectures in courses 1 and 3.

In addition to the above formal courses there is held a weekly Colloquium, or meeting for the informal discussion of subjects not treated in the lectures, and for the presentation by the students of reports on important articles appearing in the journals. A part of the work of the colloquium consists in the systematic presentation of certain classical researches, more or less connected with the lectures, in preparing which the students make use of the original sources of information, thus gaining much acquaintance with the methods of the masters in research. The work of the colloquium has an excellent effect in training students to present their ideas in a systematic manner before an auditory.

Among the various lines of investigation now attracting the attention of the physicists the following are preëminent in importance. First, the interrelations between the luminiferous ether and ordinary matter, and the modifications necessary to be made in Maxwell's theory in order to explain the known optical and electrical phenomena of bodies in motion, and that aspect of the theory which deals with the properties of the small electric bodies known as electrons. This portion of mathematical physics is extremely new, and has hardly begun to appear in university courses in this country. Second, the structure of the atoms of matter, to which the subjects of spectroscopy and the new and fascinating field of radio-activity give the most promising clew. Third, the thermody-

namics of radiation in general, which is most intimately connected with the first, and about which a similar remark may be made as to the lack of instruction.

Of branches of applied physics now awaiting the attention of the mathematical physicist may be mentioned meteorology, seismology, and geophysics in general, in all of which the accumulation of experimental data is ahead of the development of theory, to such an extent in meteorology that Professor Arthur Schuster has said that it would be advisable to suspend all meteorological observations for the next ten years, until the theory should have in some degree caught up with the mass of information already accumulated. The theory of meteorology depends on complicated applications of hydrodynamics and thermodynamics; so as to make great demands upon the mathematical physicist, but the field is a rich one to him possessed of the skill to cultivate it. The study of earthquake phenomena is one that is now becoming of great importance in this country, while the investigation of terrestrial magnetism has lately made great advances.

It is almost obvious to the trained investigator that no one can expect to become a physicist of the first rank without a thorough training in mathematical physics, as without that the results of experiment will never be collected into a coherent system worthy the name of an exact science. Furthermore all mathematical physics must rest upon mechanics, the principles of which are of an importance transcending that of any other branch of natural science. It is for this reason that the courses in physics in this department begin with mechanics, and are developed progressively in a systematic manner. They have the advantage of having been deliberately planned for the needs of students of pure physics, as experience has shown them to be prepared by the various colleges, and of being all delivered by the same person, so that logical consistency and continuity of method are assured. The waste of

time often incurred by repetitions of the same subject and of changes of notation by various instructors is thus totally avoided. Attention is called to the fact that no branch of physics is left unprovided for in the course of lectures.

The aim of the department is to insure in its students some acquaintance with all the various fields of experimental physics, to develop in them the power of exact measurement, to accustom them to exact reasoning from experiment to theory, and to encourage original research conducted on a sound basis. To this end students will be put to work in the laboratory upon experiments of sufficient difficulty to give them skill in measurements of precision, and to enable them to become familiar with the precautions and corrections necessary to be employed in exact work. After a sufficient amount of experience has been gained, and the student has shown himself to be possessed of sufficient originality to warrant independent investigation, he will be encouraged to take up for himself an original research in the hope of making a personal contribution to science. In this research he will have at all times the benefit of the direction and advice of the professor.

It should be urged upon intending students to prepare themselves, not only in ordinary laboratory measurements, but also in mathematics, the lack of proper mathematical preparation being a serious drawback to the appreciation of the lectures. In particular may be recommended for study not merely those portions of the calculus which deal with the working out of many indefinite integrals, etc., but the theoretical portions which deal with the ideas of partial derivatives, definite integrals, and their practical manipulation, together with enough analytic geometry to involve the properties of lines and *surfaces* of the second order, and a fair amount of the elements of determinants. As suitable textbooks for preparation may be recommended to the student Lamb's, Osgood's or Gibson's Calculus, C. Smith's Analytical

Geometries, and Muir's or Hanus's Determinants. Appell, *Eleménts de l'analyse mathématique* may be very strongly recommended to the intending student for study before and during his course at the University.

It cannot be too strongly urged that the student should, from the beginning, be able to read French and German with ease and to make use of works in them.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

1. The ability to read at sight specimens of scientific French and German, tested before the first of November preceding the Doctor's examination by a committee of two members of the Faculty.

2. The successful passing of an examination upon the general subject of Experimental Physics[1] and upon the subjects named above in the regular course in Theoretical Physics, as a major requirement, together with an examination in one minor subject, *to be determined in each particular case by the head of the Physical Department.* This subject will be Mathematics or Chemistry.

3. The presentation of a satisfactory dissertation, involving a substantial amount of original work, and forming a contribution of value to pure science. The presentation of the dissertation is a prequisite to examination. The time of residence necessary for the proper fulfilment of the above requirements will generally be at least three years, of which at least one will be very largely devoted to work on the dissertation. Students will not be encouraged to enter upon the work of a dissertation until they have acquired sufficient experience to enable them to specialize with advantage.

The aim of the department is to produce physicists rather than electricians, acousticians, opticians, engineers, or narrow specialists of any sort, for although in the nature of things one will be obliged to know more of one subject than of others, yet it seems evident that no thorough knowledge of any branch can be gained without a comprehensive view over the whole subject. Without this the specialist, or the experimentalist lacking a knowledge of mathematics, will continually be falling into pitfalls which the more wary avoid. Furthermore it can be but a detriment to science to encourage research in new fields by immature and ill-prepared minds and hands.

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[1] Every student is recommended to provide himself with Winkelmann's *Handbuch der Physik* as a work for continual reference.

The following statement is here inserted for the benefit of students of mathematics.

The minor in Mathematical Physics consists of the subject-matter of courses 1, 2, 3, and 10, which are intended to constitute the equivalent of five hours a week for one year. Course 10 is given in alternate years to the other courses. The subject-matter of the course is contained in Dr. Webster's treatise on *Dynamics* and Riemann-Weber's *Partielle Differentialgleichungen.*

THE LABORATORY

The laboratory occupies three floors of one wing of a large well lighted building free from disturbances, and admirably adapted to the purposes of a physical laboratory. On the ground floor is a room extending across the end of the building forty-five feet long by twenty-two feet wide, with windows on three sides, above which are three similar rooms. A lift running from the bottom to the top floor affords means of transporting apparatus, while its shaft furnishes space for manometer or barometer tubes. In the lower room are four piers with heavy stone tops, and two others below the floor on which can be placed heavy tables.

Also on the ground floor is a large dark room, partially below ground, in which the temperature is tolerably constant, containing a very large and heavy pier. The engine and storage-battery room contains a kerosene engine and dynamo on the same foundation and sixty storage cells of ten amperes capacity, constituting the power-supply. The engine may be started at a few moments notice, even at night. The storage cells are conveniently arranged so that each one is accessible from each side, from above and below, and the ventilation is excellent, while the room is as light and clean as the work-rooms. Distributing switchboards allow the current from the dynamo or any section of the battery to be supplied to any of the rooms. On the same floor are three rooms con-

stituting the workshop, one of the most important parts of a research department of physics. The first room is devoted to wood-working and pattern-making, and accommodates also a bench for soldering. The next room contains the machinist's bench, two engine-lathes and planer, and the third room a Rivet precision bench-lathe, jeweller's lathe and drill-press. There is no countershafting in the building, each tool being driven by a separate electric motor, while the capacity of the battery is such that for ordinary purposes it is not necessary to drive the engine for the shop alone, so that perfect quiet and steadiness are ensured. In the shop are executed all repairs and alterations of apparatus, and the new apparatus requiring continual experiment is constructed. Most of the principal pieces of apparatus belonging to this department have been thus constructed. In this manner, by having a mechanic always present, an extremely great economy in time and money is effected, and vexatious delays, which would otherwise completely arrest the progress of the work, are avoided. Facilities and encouragement are given to the students to construct apparatus for themselves.

On the main floor are the lecture room, the director's office, the large room used as the director's private laboratory and apparatus room, and three other convenient rooms for research. Two of these are arranged so that they may be darkened for photography, and are also fitted with chemical hoods. The large room on the top floor is devoted to the Rowland twenty-foot diffraction grating, and has a photographic dark room attached. There has been recently constructed a storage battery of two thousand small cells for researches requiring a constant source of high potential. This battery is conveniently housed next to the grating room. Every room in the laboratory contains sinks, gas and electric light connections, and several circuits connecting with the switchboard in the battery-room.

The laboratory is will equipped with apparatus for research, besides having the facilities above described for the construction of instruments of any sort needed for that purpose. In addition may be mentioned a large collection of diagrams illustrative of mathematical physics, many of them being originals of the figures in Professor Webster's "Electricity and Magnetism" and "Dynamics," and a number of interesting models used in teaching dynamics, thermodynamics, and electricity. Among them are Maxwell's Dynamical Top and a number of other interesting tops, Maxwell's and Rayleigh's induction models, Gibbs's, van der Waals's and other thermodynamical surfaces. This collection of drawings and models can probably not be matched in this country, and is continually being increased.

The laboratory affords so much space that it is rarely necessary to put more than one student in a single room. Every student receives personal attention in the laboratory from the professor whenever he needs it, and is continually in receipt of instruction and suggestion by personal contact, the best form in which information can be imparted. Emphasis should be laid on the advantage to the research student of the contact with a professor who has no other duties or interests than the furtherance of research, in an institution devoted to this as its main object.

THE LIBRARY

In the library Clark University has one of its strongest features. With a large separate building, administered in the most liberal manner with a view to the advantage of the research student, and with ample funds for the purchase of books, its facilities in the Department of Physics can hardly be surpassed. It may be said to contain all of the most important works in many languages, and is continually kept

up to date, any book wanted needing only to be mentioned to be procured. The library is particularly rich in journals, among which are included the transactions of the learned societies of England, France, Germany, Italy, Austria, Holland, and Belgium. Other sets are being continually added. A list of journals will be found at the end of this circular. There are few subjects connected with physics which may not be thoroughly studied in this library.

III. CHEMISTRY

Within the past few decades chemistry has been gradually passing from the larval state of a descriptive science into a higher state of development, the theoretical stage. This transition has given to the ancient science, not only a new beauty and usefulness, but also an amazing *will to grow.*

Some liken the new chemistry to a tower in the earliest stages of construction, with a host of men swarming on the scaffolding, busily engaged in adding stone after stone to the promising structure.

From the pure science this intense constructive activity has spread, as might be expected, to the applied branches, notably the American chemical industries. Where twenty-five years ago the chemist was employed, and allowed, to do nothing but routine testing, to-day research laboratories are in active operation, whose members are expected to invent, develop, and improve something somewhere in the processes of manufacture. American enterprise has discovered a way toward the highest utilization of the country's wealth in setting trained ingenuity at work in chemical research laboratories.

The equipment of the industrial chemist, as well as of the competent teacher, must consequently consist, not so much in a memorized collection of formulae and processes, or of heterogeneous information in the chemistry of the manufactures, as in a clear critical understanding of the principles of pure chemical science and in some experience in grappling with difficulties. The desire for *such* knowledge, and the courage and perseverance necessary in attacking problems, are acquired only through research. And hence *a depart-*

ment of chemistry, particularly a graduate department, must be primarily a department of chemical research.

With this principle in view, the activities of all members of this Department, both instructors and students, are devoted mainly, almost entirely, to research. The number of lectures is reduced to a reasonable minimum. Students take up research from the first day of their residence in the Department, and are directed to devote about one-quarter of their time to all scholastic work combined, and the remaining three-quarters to research. The investigations in which they are expected to engage are, as a rule, entensive in scope and occupy two years at least, in some cases three years or more. This makes it possible for the student to found his Doctor's degree, not on a perfunctory dissertation, but on a study and contribution that will give him scientific confidence for years to come.

Even the lecture courses, instead of forming descriptive presentations of existing chemical knowledge, are conducted, as far as possible, on a research plan. In the first place, the material of the lectures is derived, not from text-books, but from the original literature, and the student is constantly referred to original communications for accessory study. Then, each topic is approached by the lecturer, not as a chapter in a book, but as a problem in nature. The topic is introduced by an estimate of its importance and of its bearing on other problems. This is followed by an account, on the historical plan as far as possible, of the extent to which the problem has been solved, of how this was done, and of how much is not yet solved, with suggestions as to practical methods by which solution might be obtained. It is believed that such *critical mode* of study is the true characteristic of university work; perhaps the only characteristic that can keep university lectures from forming a continuance of the teaching of the lower schools, which often permanently

impairs the student's most precious possession: his inherited creative instinct.

Specialized courses are offered on topics of history of chemistry, chemical dynamics, heterogeneous equilibria, organic synthesis, stereo-chemistry, electro- and thermo-chemistry, applications of thermodynamics to chemistry, etc., and the student is expected to attend them regularly. To aid students not quite prepared for work of this kind, simpler lecture and laboratory courses will be offered in general inorganic chemistry, organic synthesis and analysis, physical chemistry, etc.

Part of the scholastic work of the department consists in Colloquium exercises, students and instructors alike presenting accounts of current chemical research or, at times, delivering formal lectures on classical achievements of the past, or on the life and life-work of celebrated masters of chemical research.

Finally, several times in course of the academic year (but not oftener than once a month) lectures will be delivered here by active chemical investigators from other institutions—lectures dealing generally with the aims and methods of their own investigations. The Department expects much stimulus from such occasional contact with brilliant and hopeful scientific men.

The research work conducted in the Department runs mainly along the following lines: 1. Experimental and theoretical study of the deviations of fact from accepted principles of *general chemistry;* 2. Experimental study of organic substances and reactions from the standpoint of chemical statics and dynamics: *physico-organic chemistry.* Of course, promising investigations may be taken up, from time to time, along other lines as well.

Instead of more or less insignificant pieces of work being "assigned" to students for their first experience in research,

they will be made, if they desire it, *collaborators* of their professor in his own investigations (unless, indeed, they bring forward practicable research projects of their own). Nothing could more certainly assure constant and intimate contact between professor and student and the student's really receiving the best that the Department can offer: individual guidance.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Strictly speaking, there are no formal "requirements" for the Doctor's degree in this Department. The general University Faculty expects in all cases one year's residence. Otherwise the Department is entirely autonomous in its organization of the training for the degree and in its final estimate of the candidate's maturity. *This imposes upon both instructors and students the duty of zealously guarding the honor of the degree and of maintaining in the Department the highest attainable intellectual standard.*

The time necessary to qualify for the degree of Doctor of Philosophy will depend in each case partly upon the ability of the student, but mainly upon the exigencies of his investigation. Three years will not be too long in most cases.

If the student does not possess, at the time of his joining the Department, a good reading knowledge of both German and French and a working knowledge of analytical geometry and the calculus, he ought to acquire such knowledge as early as possible. Experience shows that students learn a considerable amount of mathematics through the special course in chemical mathematics offered here, and also through the courses in physical chemistry. The Colloquium work invariably leads to improvement of the student's knowledge of languages.

The student is advised and expected not to neglect any

one of the great branches of modern chemistry by "majoring" in one of them and "merely minoring" in the others. The examinations for the degree will consist, on the one hand, in a series of partial tests distributed throughout the candidate's period of residence and, on the other hand, in a general final examination in the several branches of chemical science, including organic and physical chemistry, and chemical statics and dynamics; also in one minor subject *to be determined in each case by the Head of the Chemical Department.*

But the real basis upon which the degree will be conferred will be a dissertation forming, in the opinion of the Head of the Department, a genuine contribution, either purely theoretical or experimental, to chemical science.

If a candidate shall have shown in his research signs of true originality of thought, the Doctor's degree will be conferred upon him *cum laude.*

THE MASTER'S DEGREE

The University does not require an original scientific contribution in connection with the Master's degree. In this Department an applicant is, accordingly, offered free choice between founding his degree on research or on purely scholastic work. It is a pleasure to record that as yet applicants have invariably chosen the former, in spite of being warned that research is uncertain of outcome and more difficult, and might prolong to two years the time necessary for the attainment of the degree.

In the scholastic exercises no qualitative distinction is made between work for the Master's and that for the Doctor's degree in chemistry. The former degree is considered a stepping-stone to the latter.

COURSES GIVEN DURING THE YEAR 1910–1911

A. *Professor Rosanoff's Courses*

1. The Law of Mass Action, Tuesdays and Thursdays at 10.45 to 12.00. First half-year. This specialized course deals almost exhaustively with the methods and results of static and kinetic studies in homogeneous systems. Together with the course mentioned in the following paragraph it is expected to aid the student in acquiring a solid working knowledge of the modern theory of chemical reactions.

2. Equilibrium and Velocity of Changes in Heterogeneous Systems, from the Viewpoint of the Phase Rule, the Law of Mass Action and the Principles of Thermodynamics. Tuesdays and Thursdays at 10.45 to 12.00. Second half-year.

3. Organic Stereo-Chemistry, Fridays at 12. This course presents an opportunity for a review of several important chapters of organic chemistry, especially the carbohydrates, the structure of benzene and of ethylenic compounds, etc.

4. Colloquium, *directed jointly by the members of the departmental staff.* This is held once in two weeks during the first half-year and once a week during the second half-year, Tuesday afternoons from 4 to 6 or Tuesday evenings from 8 to 10.

B. *Dr. Merigold's Course*

5. The Principles and Methods of Atomic Weight Determinations, Wednesdays at 10 A.M. The object of this course is to acquaint the student with the methods of atomic weight research. A number of classical contributions from Professor Richards' and other laboratories are studied analytically, with especial emphasis on the processes employed in the high purification of inorganic substances.

C. *Dr. Clark's Course*

6. The Carbocyclic Compounds, Tuesdays at 9 A.M. This course attempts a critical study of the physical and chemical methods used in determining the constitution of carbocyclic compounds. Among the substances included are the more important derivatives of benzene, naphthalene, anthracene, furfurane, thiophene, pyrrol, coumarone, indol, the azoles, pyrones, pyridines, quinolines, acridines, and azines.

D. *Professor Story's Course*

7. Practical Applications of Mathematics, Tuesdays and Thursdays at 12. The aim of this course is to help the student acquire that mathematical knowledge without which the professional education of a chemist, whether engaged in teaching or in industrial work, is to-day no longer complete.

E. *Professor Noyes's and Other Special Lectures*

8. In the capacity of Non-resident Lecturer on Chemical Research in this University, Professor Arthur A. Noyes presented here, on December 13th and December 15th, an account of the present state of the study of the anomalous behavior of strong electrolytes carried on in the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology.

On January 20th Professor Arthur Michael lectured on the aims and results of his present researches on reversible organic reactions.

Arrangements are being made for other special lectures and brief lecture courses to be given here, during the remainder of the academic year, by prominent chemical investigators.

ONE CANDIDATE'S EQUIPMENT

In order to give anyone who may be interested some insight into the actual working and results of the arrangements made in the Department, it seemed desirable to make a statement as to the work here of one student, at present a maturing candidate for the Doctor's degree:

I. Research

The candidate began his research, dealing with the cause of the relative velocities of certain organic reactions, in October, 1908, and has continued the study ever since. The work consists in precise measurements of reaction velocities, combined with other physico-chemical measurements and preparative organic work. It has given the candidate no little insight into the methods of chemical kinetics and statics.

II. Courses Taken

First Year:

1. The hydro-aromatic series, including the monocyclic and polycyclic terpene bodies (Dr. Rosanoff).
2. Organic stereo-chemistry (Dr. Rosanoff).
3. Special methods of inorganic analysis (Dr. Merigold).
4. Organic synthesis (Dr. Rosanoff).
5. Chemical mathematics (Dr. Story).

Second Year:

6. General and physical chemistry, especially gases, liquids, and solutions (Dr. Rosanoff).
7. Dyestuffs, alkaloids, and polypeptides (Dr. Clark).
8. Inorganic stereo-chemistry; radio-activity (Dr. Merigold).
9. Thermodynamics, with some emphasis on applications to chemistry (Dr. Webster).
10. Supplementary and explanatory course in thermodynamics (Dr. Hubbard).

During his second year the candidate also acted as teaching assistant in organic synthesis in the Collegiate Department (one afternoon a week).

Third Year (current):

11. The law of mass action in homogeneous systems (Dr. Rosanoff).
12. The phase rule and the law of mass action in heterogeneous systems (Dr. Rosanoff).
13. Constitution of derivatives of benzene, naphthalene, anthracene, etc. (Dr. Clark).
14. Methods of atomic weight determinations (Dr. Merigold).

During the current year the candidate is also attending for the second time Dr. Rosanoff's lectures on organic stereo-chemistry and is spending a small fraction of his time as Research Assistant in the University Department.

III. Papers Reported by the Candidate in Colloquium

1. Jean Rey. "The Increase in Weight of Tin and Lead on Calcination." (Alembic Club Reprints).
2. Mayow. "Medico-Physical Works." (Alembic Club Reprints).
3. Priestley. "The Discovery of Oxygen." (Alembic Club Reprints).

4. Scheele. "The Discovery of Oxygen." (Alembic Club Reprints).
5. Ipatieff (pyrogenetic researches), *Berichte*, *34*, 596 (1901).
6. Ipatieff (same subject), ibid., 3579 (1901).
7. Ipatieff (same subject), ibid. *35*, 1047 (1902).
8. Perkin and Pickles (synthesis of terpenes), Trans. London Chem. Soc., *87*, 639 (1905).
9. Perkin and Matsubara (same subject), ibid., *87*, 661 (1905).
10. Baeyer (terpenones of the carvone group), *Berichte*, *27*, 1916 (1894).
11. A. A. Noyes (conductivities at high temperatures), J. Am. Chem. Soc., *30*, 335 (1908).
12. A. A. Noyes (conductivity and ionization of polyionic salts), J. Am. Chem. Soc., *31*, 987 (1909).
13. Bredig (osmotic pressure and the Van der Waals equation), *Zeit. physik. Chem.*, *4*, 444 (1899).
14. A. A. Noyes (same subject), ibid., *5*, 53 (1890).
15. Abegg (same subject), ibid., *15*, 254 (1894).
16. Freund, Martin, and Achenbach (action of hydroxylamine on certain derivatives of anthraquinone), *Berichte*, *43*, 3251 (1910).
17. Rabe (on a peculiar connection between the strength and action of acids), ibid., *43*, 3308 (1910).
18. Lecture on the manufacture of essential oils (based largely on Muspratt).
19. Lecture on the Grignard reaction.
20. Account of the life of Lord Kelvin.
21. Account of the life and work of Van't Hoff.
22. Lecture on the results of the candidate's own first two years of research.

Several further papers will be reported on by the candidate during the remainder of the current year.

The instructors believe that the candidate will have acquired here a fund of chemical culture and earned for himself a degree that will be respected wherever he goes, either in this country or abroad.

FACILITIES

The University chemical laboratories occupy a considerable part of the laboratory building. The storerooms contain

an unusually large collection of organic preparations, besides all the ordinary inorganic chemicals. The collection of physico-chemical apparatus, including the latest form of Pulfrich's refractometer, a fine spectroscope, a large Hilger quartz spectrograph, a Burkhardt calculating machine, an Altschul apparatus for measuring critical pressures, specially constructed large constant-temperature stillheads, a set of excellent thermostats, sets of fine thermometers, etc., is sufficient for most ordinary purposes. Whatever special apparatus and chemicals are needed in connection with the work of research are ordered at once, every reasonable effort being made to help the student obtain a maximum of results with a minimum expenditure of time and energy. In this connection it may be mentioned that the Department is at liberty to use the services of the skilled mechanician regularly employed by the Department of Physics. Students will themselves prepare their chemicals, or build their research apparatus, only in those case in which the Director may consider such work especially instructive to them.

The Director of this Laboratory is Secretary of the Association of American Chemical Research Laboratories, formed at the second decennial celebration of Clark University in 1909. *Inventories of the more important research laboratories are kept here, and any chemical needed in an investigation, if not in our own stock, is promptly supplied by some other member of the Association.* Such exchange of chemicals by laboratories entitled to duty-free importation has recently been declared by the authorities at Washington to be perfectly legal. It is certainly of the greatest help to members of this Department.

THE LIBRARY

The Library of Clark University has, independently of the other departments, a magnificent endowment of its own. Its chemical collection contains complete files of all the more important journals in English, German, and French, and a rapidly increasing number of general treatises, monographs, and reference works. A list of chemical journals may be found at the end of this circular. The income of the library permits of purchasing at once *all* books needed by anyone engaged here in chemical research.

Part of the collection, including the files of the *Zeitschrift für physikalische Chemie*, the *Berichte der deutschen chemischen Gesellschaft*, the *Transactions of the Chemical Society of London*, the *Journal of the American Chemical Society*, the *Chemisches Zentralblatt*, and a number of reference works, forming a small departmental library proper, is kept in one of the laboratory rooms and is accessible to all members of the Department at all times. The departmental library, for the establishment of which the Department is deeply indebted to Dr. Louis N. Wilson, University Librarian, is one of the most valuable aids in the work of both instructors and students. It will be gradually enlarged.

SCHOLARSHIPS AND FELLOWSHIPS

The Department has at its disposal several Scholarships and Fellowships, which will be awarded each year to the ablest and best recommended applicants. Scholars, and especially Fellows, will coöperate with the Director in maintaining a harmonious and scientific atmosphere in the Department and in promoting all the ends of the University. They will have no duties besides that of making the best use of the facilities for study and research offered to them.

RESEARCHES CARRIED ON IN THE DEPARTMENT SINCE THE INSTALLATION OF ITS PRESENT HEAD, SEPTEMBER, 1907

1. Practical elaboration of a new method for determining the partial vapor pressures of organic mixtures, and determination by means of it of the vapor pressures of a number of typical binary mixtures (published; *crowned by the American Chemical Society with the Nichols gold medal of its New York Section*).

2. A quantitative study of the Victor Meyer Esterification Law and the Steric Hindrance hypothesis (published).

3. A quantitative study of steric hindrances in the esterification of fatty acids (published).

4. Perfection of a precise and rapid method for determining halogens in organic compounds (published).

5. A study of the transformation of aldohexoses into alcohol by ferments, enzymes, and alkalies (uncompleted).

6. A new relationship between the vapor pressures of binary mixtures and a general quantitative theory of fractional distillation (ready for publication).

7. Experimental study of fractional distillation in the light of the results of the preceding research (ready for publication).

8. A theoretical study of the variation of the vapor composition of binary mixtures with the temperature (ready for publication).

9. A study of the mechanism of iodination in the aromatic series by halogen carriers (uncompleted).

10. A new study of steric hindrances in esterification (in progress).

11. A precise quantitative study of the phenomena of direct esterification and ester hydrolysis (in progress).

12. A study of the kinetics of certain inorganic reactions (temporarily interrupted).

13. A precise study of the decomposition of tertiary amyl esters (in progress).

14. A peculiar transformation of benzo-bromamide (temporarily interrupted).

15. An improved method for the preparation of acetamide (ready for publication).

16. Definition of an Ideal Gas (in collaboration with Professor Webster; published).

17. A new study of the Duhem-Margules equation (in collaboration with Professor Story; nearly ready for publication).

18. A theoretical revision of some of the principles of the theory of solutions (in progress).

19. A new study of the dynamics of sugar inversion (in progress, one part ready for publication).

20. A rapid method for measuring partial vapor pressures (ready for publication).

21. Limitations of the constant-temperature stillhead (ready for publication).

22. A study of esterification equilibrium in the gaseous state (in progress).

23. An improvement of the preparation of para-nitro-phenol (published).

24. Determination of the relative strengths of organic acids by a new physico-chemical method (in progress).

25. A study of the decomposition of nitroso-compounds by potassium hydroxide (in collaboration with Professor W. A. Noyes, of the University of Illinois; in progress).

26. The working of the constant-temperature stillhead in the case of mixtures with maxima or minima in the boiling-point curves (ready for publication).

27. A new lamp, giving an exceedingly intense monochromatic light (ready for publication).

LIBRARY

The Library is under the control of a Library Committee, appointed by the Trustees, of which the President of the University is *ex officio* chairman. The duties of this committee are to advise concerning the arrangement, cataloguing, use of books, and other matters pertaining to the Library not reserved to the Trustees nor otherwise provided for.

The Library contains about 55,000 bound volumes and pamphlets, and the reading-room receives over 400 journals.

The books are grouped as follows:

A Works of General reference
B Journals
C Mathematics
CD Math.-Physics
D Physics
DE Physical Chemistry
E Chemistry
F Biology, Zoölogy, Botany, Physiology, Neurology
G Geography
H Pathology
I Psychology
J Philosophy
ℵ Religious Psychology
L Biography
M Anthropology
N Education
O General science
P History
Q Law
R Political and Social Science
S English
T Modern Languages
U Classics
W Practical Arts
X Library Science
Y Art
Z Manuscripts

Tuesday and Friday mornings, each week, all books recently added to the library are placed upon a table in the Reference section where they remain for three days. This affords the members of the University and College an opportunity to examine the new books in all departments before they are placed upon the shelves for circulation.

About once a month, during term, by the courtesy of our booksellers, new books are placed for inspection on one of the tables in the Reference section. Any member of the University or College may recommend the purchase for the library of books thus displayed, and such recommendation will receive prompt attention.

All books are classified by the heads of departments and particular attention is paid to the needs of students engaged in research work. The library already possesses a good collection of complete sets of the best scientific periodicals. It makes liberal purchases for individual needs and supplements these by drawing upon the resources of the older and larger libraries through the inter-library loan system. During the past year 420 volumes were borrowed from, and 316 volumes lent to, other libraries. The number of books added each year is about four thousand volumes.

All the privileges of the library are open to all members of the University, and each member has direct access to every book and journal.

The library is open from 8 a.m. to 6 p.m. each week day from Sept. 1 to July 1. During July and August it is open from 8 a.m. to 5 p.m. from Mondays to Fridays, and on Saturdays from 8 a.m. to 12 m. The library is closed July 4th, Thanksgiving Day and Christmas Day.

Outside the University are found:

The Library of the American Antiquarian Society, organized in 1812, and containing over 120,000 volumes, accessible to all members of the University.

The Worcester Public Library, containing 600 newspapers and magazines and 175,000 volumes, has, in the past, to some extent supplemented the scientific publications purchased by the University, and all its privileges are accessible without charge.

The Library of the Worcester District Medical Society of about 10,000 volumes, is also free to all members of the University.

The following journals relating to the work of this Division are in the Library.

AMSTERDAM.

Koninklijke akademie van wetenschappen. Verhandelingen, 1854 to date. Complete.

Revue semestrielle des publications mathématiques. 1893 to date. Complete.

BALTIMORE.

American chemical journal. 1879 to date. Complete.

American journal of mathematics. 1878 to date. Complete.

BANGKOK.

Siam society. Journal. 1905-07.

BERLIN.

Berliner mathematische Gesellschaft. Sitzungsberichte. 1902 to date. Complete.

Chemisches Centralblatt. 1897 to date. Complete.

Deutsche chemische Gesellschaft. Berichte. 1868 to date. Complete.

Fortschritte der Physik. 1847 to date. Complete.

Jahrbuch über die Fortschritte der Mathematik. 1868 to date. Complete.

Journal für die reine und angewandte Mathematik. 1826 to date. Complete.

Königlich-preussische Akademie der Wissenschaften. Mathematische und naturwissenschaftliche Mittheilungen aus den Sitzungsberichten. 1882-97. Complete.

Zeitschrift für angewandte Chemie. 1888 to date. Complete.

BOLOGNA.

Istituto di. Bologna. Reale academia delle scienze.

Commentarii. 1731-1791. Complete.

Novi commentarii. 1834-1849.

Memorie fis. e mat. 1806–1910.

Memorie. 1850 to date. Complete.

Scientia; rivista di scienza. 1910 to date. Complete.

BOSTON.
American academy of arts and sciences. Proceedings. 1870 to date. Complete.
North American Review. 1815–1886.
Technology review. 1899 to date. Complete.
BOULDER, COLORADO.
University of Colorado. Studies. 1902 to date. Complete.
BRAUNSCHWEIG.
Deutsche physikalische Gesellschaft. Berichte. 1903 to date. Complete.
Jahresbericht über die Fortschritte der Chemie. 1847 to date. Complete.
BRESLAU.
Kaiserlich-Leopoldinisch-carolinische deutsche Akademie der Naturforscher. 1843.
BRUXELLES.
Académie royale des sciences des lettres et des beaux-arts de Belgique.
Bulletins. Ser. 3. 1889 to date.
Mémoires couronnés et mémories des savants étrangers. 1889-90.
CAMBRIDGE, ENGLAND.
Cambridge philosophical society.
Proceedings. 1843 to date. Complete.
Transactions. 1822 to date. Complete.
CAMBRIDGE, MASSACHUSETTS.
Science. 1883 to date. Complete.
CHARLOTTESVILLE, VIRGINIA.
Annals of mathematics. 1884 to date. Complete.
CHICAGO.
Astrophysical journal. 1895 to date. Complete.
Terrestrial magnetism. 1896 to date. Complete.
COLUMBIA, MISSOURI.
University of Missouri studies. Science series. vol. 1. 1905-07.
DRESDEN.
Zeitschrift für Chemie und Industrie der Kolloide. 1906 to date. Complete.
EASTON, PENNSYLVANIA.
American chemical society.
Chemical abstracts. 1907 to date. Complete.
Journal. 1879 to date. Complete.
Proceedings. 1878 to date. Complete.
EDINBURGH.
Edinburgh mathematical society. Proceedings. 1884-1907.
Edinburgh philosophical journal. 1819-1826.
Edinburgh royal society transactions. 1873 to date. Complete.
GÖTTINGEN.
Königliche Gesellschaft der Wissenschaften. Nachrichten von der k. Gesellschaft der Wissenschaften und der Georg-Augusts-universität. 1853 to date.
GREIFSWALD.
Archiv der Mathematik und Physik. 1901 to date.
HAARLEM.
Hollandsche maatschappij der wetenschappen. Archives néerlandaises des science exactes et naturelles. 1866 to date. Complete.
HALIFAX.
Nova Scotian institute of science.
Proceedings and transactions. Halifax. 1890 to date. Complete.

HALLE.
Zeitschrift für Electrochemie. 1895 to date. Complete.
HAMBURG.
Mathematische Gesellschaft. Mittheilungen. 1890 to date. Complete.
Zeitschrift für anorganische Chemie. 1892 to date. Complete.
HEIDELBERG.
Annalen der Chemie. 1832 to date. Complete.
INDIANAPOLIS.
Indiana academy of science. Proceedings. 1895-98.
ITHACA.
Journal of physical chemistry. 1896 to date. Complete.
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